# LICHENS AND AIR QUALITY

# IN THE MT. BALDY WILDERNESS AREA

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# INTRODUCTION

This study is the result of recommendations resulting from an air quality workshop in March 1990 (Blankenship, 1990).

Numerous studies in various parts of the world have established that lichens are useful bioindicators of air pollution, as recently reviewed by Nash & Wirth (1989) and Galun & Ronen (1988). Many of these studies have been field studies around major urban centers or around known point sources of specific pollutants. A wide variety of approaches, many of which combine data on lichen distribution with data on actual measurements of pollutant concentrations in the air and in the lichens themselves, have been used. A more limited number of studies have been experimental (fumigation or transplants).

In areas where extensive and detailed historical records are available, as in Europe and a few parts of North America, re-studying those areas has often shown changes in the lichen vegetation that can be correlated with changes in pollution levels. Unfortunately, in most parts of the United States, such historical records are not available. However, an increasing number of studies have begun to collect baseline data in national Parks, Wilderness Areas, and other non-urban areas for the purpose of being able to follow future changes in air quality in those areas.

In Arizona and adjacent areas of southwestern North America, although major surveys of lichens have been made in a few areas starting in the 1960's, and we have very recently initiated a long-term international project of preparing a lichen flora of the Sonoran Desert region, the systematics and distribution of lichens of this region are still poorly known. Only a few studies, such as those of Nash (1974) and Wetmore (1987) have explicitly focused on lichens in relation to air pollution in Arizona.

Nash (1977) surveyed the lichens of the White Mountains and reported 72 species collected in 1973 and 1974 from the Mt. Baldy Wilderness area (West Fork trail, between Sheep's Crossing and the summit of Mt. Baldy, 2710-3520 m). Additional collections from the area were made by Nash in 1983.

The present study extends the results of these earlier surveys by making a more thorough survey of the Mt. Baldy Wilderness, including quantitative sampling of lichens on selected substrates. It also provides a preliminary review of the literature on the pollution sensitivity of the lichen species found in this wilderness. Although this wilderness is located in an area that has so far been exposed to few major local sources of pollution, the data presented in this study will be useful in monitoring future increases and in making comparisons with other areas currently exposed to high levels of pollution.

## STUDY SITE

The Mt. Baldy Wilderness Area (Apache National Forest) is located in Apache County, Arizona, in the White Mountains, ca. 15 miles SW of Springerville (Fig. 1). The Wilderness covers 7,079 acres, and elevations range from 2700 to 3500 m (9,000 to 11,550 feet) above sea level. Most of the rocks are volcanic (mainly basalt). The average annual precipitation in the Mt. Baldy Wilderness is about 100 cm (45 inches), of which half comes as snow. Further details on the geology and other physical features of the White Mountains are given by Merrill and Péwé (1977).

Much of the Wilderness is dominated by Spruce-Fir forests (Picea englemannii-Abies lasiocarpa) with open meadows. The middle elevations along the East Fork trail are dominated by Douglas Fir forest (Pseudotsuga menziesii). Other important tree species that provide substrates for lichens include Quaking Aspen (Populus tremuloides) and Ponderosa Pine (Pinus ponderosa). At the highest elevations, near the summit of Mt. Baldy, there are fairly extensive grass dominated "bald" areas, which have a subalpine flora.

At present the nearest major source of air pollution is a power plant near St. Johns (ca. 67 km NNE of the Wilderness). In the past, significant amounts of pollution also came from copper smelters ca. 100 km SSE of the Wilderness, and from industries in the Globe/Miami area (over 160 km WSW of the Wilderness), but these sources probably have minimal impact on the Mt. Baldy Wilderness today.

During the summer and fall of 1990 and in the earlier surveys by Nash, lichens were surveyed along the two main trails traversing the Wilderness (East Fork and West Fork trails). The locations of specific collecting or sampling sites are shown in Fig. 1.

## METHODS

Nomenclature of lichens in this report generally follows Egan (1987). Specimens are deposited in the herbarium at Arizona State University (ASU), with duplicates, when available, being deposited in the herbarium at Brigham Young University (BRY), Provo, Utah.

### Quantitative Sampling

In addition to the floristic survey, four kinds of quantitative sampling of lichens were conducted in the Wilderness during the summer of 1990, in the vicinity of the East Fork trail. Voucher specimens were collected in cases where species could not be reliably determined in the field.

Presence of different lichen species on 20 cedar fenceposts along the wilderness boundary near Phelps cabin was recorded. The fenceposts were selected randomly, with 10 on the south side of the gate (near the creek); 10 on the north side (drier area).

Lichens on branches of Picea englemannii were surveyed in a stand of trees located within 20 m of a small stream south of the trail ca. 3/4 mile west of the eastern boundary of the Wilderness (ca. 2950 m elevation). Twenty trees (5 groups of 4, at 20 m intervals along a transect tape), with circumferences of at least 0.4 m, were selected using the point-quarter method (Cottam, G., et al., 1953, Ecology 34: 741-757). The presence of Pseudevernia intensa, Usnea cavernosa, and Usnea spp. (tufted forms) on each branch of length over ½ the radius of the canopy, up to 4 m above the ground, was recorded. The circumference of the tree, height of the lowest branch sampled, and condition of each branch sampled (i.e., dead or alive) were recorded. The presence of other lichens on each tree was also noted. From these data the frequency of occurrence of the lichen taxa out of all 20 trees and all branches sampled was calculated. The distance of each tree in a group from the point on the transect tape was also recorded, so that the density of trees per hectare in the vicinity of each group of 4 trees could be calculated.

A survey of lichens on 15 randomly selected trees of Pseudotsuga menziesii was made along the East Fork trail ca. 1 mile west of the eastern boundary of the Wilderness (ca. 3000 m elevation). At each compass point, at the base and at breast height on each tree, a 20 x 20 cm quadrat was established, and percent cover of each lichen species in the quadrat was estimated. Presence of other lichen species on each tree was also recorded. From these data the mean percent cover and frequency of lichen species for each compass direction and for base and breast height were calculated.

Lichens on rock were surveyed in a patch of scree boulders in the general vicinity of the Picea sampling site. Quadrat locations were established by randomly selecting points along the transect tape and randomly determining distance from the tape (alternating left and right). The percent cover of lichen species in each 20 x 20 cm quadrat was recorded, and mean percent cover and frequency were calculated.

## Sampling for Element Analysis

Samples of several fruticose lichens (Pseudevernia intensa, Usnea cavernosa, tufted Usnea spp. (mostly U. lapponica and U. subfloridana), and Bryoria fuscescens) were collected from trees near the East Fork and West Fork trails for future analysis of element content. Care was taken to avoid collecting bark and to avoid touching the lichens by hand.

## RESULTS AND DISCUSSION

Collecting sites in the Mt. Baldy Wilderness are listed in Appendix A. At least 250 species of lichens occur in the Mt. Baldy Wilderness (Appendix B). Over 65 of these species are recorded from Arizona for the first time, and of these at least four of these are newly recorded for North America. Several may be new, undescribed species. Species lists for the major collecting areas, separated according to when they were collected (i.e., 1990 or an earlier year) are given in Appendix C. An identification key for the lichens of this Wilderness is given in Appendix D. Photographs (slides) of representative and sensitive lichen species from the Wilderness are attached to the end of this report.

### Distribution of Species by Substrate and Habitat

The results of the quantitative sampling are given in Tables 1-5. These results, and other observations, are discussed below. Aside from the results of the quantitative sampling, notes on the microhabitats are given below or in the species lists (appendices), mainly in cases where the distribution patterns were obvious and distinctive in the field.

#### Taxa on bark or wood

At least 85 species occur on bark or wood in the Wilderness. The corticolous or lignicolous lichen flora was richest on *Pseudotsuga menziesii*, *Picea englemannii*, and *Abies lasiocarpa*.

On *Pseudotsuga*, lichens occurred mainly on the trunks. For the trunks sampled along the East Fork trail (Tables 1 & 2), total lichen cover was considerably higher on the north and east (more shaded and moist) sides of the tree bases and on the north side of the trunks, than on the other exposures, and the individual species showed similar trends. Species of *Cladonia*, *Lecanora*, *Lecidella*, *Lepraria*, *Parmeliopsis*, and *Tuckermannopsis* occurred entirely or mainly on the base of the trees, with *Parmeliopsis ambigua* having the highest cover and frequency. Most of the other species occurred mainly higher on the trunks, with *Usnea* spp. having the highest cover and frequency at breast height. Only *Parmelia sulcata* occurred commonly both at the bases and higher up.

On *Picea*, lichens occurred mainly on branches. The estimated density of the trees sampled near the lower part of the East Fork trail ranged from 377.4 to 1726.1 per hectare. Their circumference at breast height ranged from 0.4-1.4 m, and the trees had their lowest branches occurring mostly at 1.5 to 2 m above ground. At least 60% of the 194 branches in the first four meters above the ground were dead. The frequencies of lichen species on *Picea* branches at this site are given in Table 3. The overall frequencies were greatest for *Pseudevernia intensa*, *Usnea* spp., *Flavopunctelia soredica*,

Pseudevernia intensa, Usnea spp., Flavopunctelia soredica, Melanelia subolivacea and Physcia stellaris. Few obvious correlations between species distributions and the density or size of the trees, or the height or condition of the branches were observed. Usnea cavernosa occurred only on trees 0.7 m or more in circumference, and occurred with equal frequency on dead and live branches. The tufted Usnea spp. had a higher branch frequency in the areas with 600 or more trees per hectare, and were much more frequent on dead branches than live ones (78% of the branches on which tufted Usnea spp. occurred were live ones). In contrast, 70% of the branches on which Pseudevernia intensa occurred were dead ones.

The species composition of the lichen flora on Abies was generally similar to that on Picea, with a few exceptions. A few species occurred on pines (mainly on wood near the base of Pinus strobiliformis).

Relatively few species, usually with low cover, occurred on Populus tremuloides, mainly on the roughened parts of the bark on a few trees: Phaeophyscia sp. and Xanthoria polycarpa (characteristic of nutrient enriched hardwood bark) were the most conspicuous lichens on Populus. Compared to some other localities in North America, the lichen flora on Populus was rather depauperate, perhaps due to the relative dryness of this wilderness, or to the lack of other, more suitable species of hardwood trees that could serve as reservoirs for propagation.

Many species occurred on wood. Caloplaca microphyllina, Cyphelium tigillare, Lecanora spp. (especially L. saligna), Rinodina sp., and tufted Usnea spp. were the most frequent taxa found on fenceposts (Table 4). Many of the species (e.g., Candelariella sp., Lecanora saligna, Physconia detersa, Rinodina sp., and Xanthoria fallax) were restricted to or more abundant on fenceposts closer to the stream (more moist), while a few (e.g., Flavopunctelia soredica were commonest on posts in the drier area away from the stream.

Taxa on soil, moss or humus

About 45 species were found on soil, moss or humus. Species of either Cladonia or Peltigera formed extensive patches (over 50% cover) on the ground in a few very localized areas. Other taxa, such as species of Lepraria, Leptogium and Nephroma, were abundant on mosses over rocks in shaded areas. Some taxa, such as Stereocaulon sasakii, were found only at the highest elevation sites.

Taxa on rock

Over 125 species were found on rock. Some species were restricted to particular types of habitats, related mostly to light or moisture.

Some species, such as some species of Acarospora and Caloplaca, Dimelaena oreina, Rhizoplaca spp. and Xanthoparmelia spp., occurred mainly on exposed boulders or outcrops in meadows, which are sunnier and may also be exposed to manuring by birds or animals. One lichen found only on such exposed boulders, Candelina submexicana, is a species normally found at much lower elevations in the Sonoran Desert. On scree rocks at low elevation near the East Fork trail (Table 5), the brown Lecidea complex had by far the highest overall cover. Rhizocarpon geographicum s.l. and Xanthoparmelia spp. were also very frequent, but lower in cover.

Many species, such as Acarospora chlorophana, Lasallia spp., Punctelia spp., Ramalina sp., Umbilicaria cinereorufescens, and Xanthoria sorediata were found only on steep cliff faces. Lecanora demissa was restricted to very shaded crevices in the cliffs. These patterns are typical of these taxa.

Some species, such as Lecanora marginata, Pseudephebe minuscula, Sporostatia testudinea are typically alpine lichens that were observed only at the highest elevation sites.

A few species characteristically occurred on rocks in or along streams, where they are at least occasionally submerged, especially Staurothele and Verrucaria, and some species of Aspicila and Lecidea s.l.

A few taxa, such as Flavopunctelia spp., occurred both on rock and bark, as commonly occurs in other localities. Some taxa that normally grow on rock (e.g., Xanthoparmelia spp.) or on soil (e.g., Cladonia spp.) occurred occasionally on bark or wood, but this is not unusual. The presence of Candelaria concolor (normally found mainly on bark) on bark is difficult to explaine, but is most likely to be due to the scarcity of roughened hardwood bark surfaces in this wilderness, and to the enrichment of trailside rocks by dust and manure (overriding the species' normal substrate preference). The possibility of a substrate switch due to greater exposure to pollution on the trees is unlikely in view of the abundance of sensitive species on trees in this wilderness.

## Comparison Between 1990 Collections and Earlier Ones

Almost all of the species that were collected in the Wilderness by Nash in 1973, 1974 or 1983 were also found in 1990, except for a few taxa. Most of the species found in the earlier collections but not in 1990 occurred only at the highest elevation sites (on or near the summit of Mt. Baldy, localities 2 and 3, not visited later), and are mostly distinctive species (not likely to be missed in 1990): Amygdalaria elegantior, Buellia lacteoidea, Diploschistes muscorum, Diplotomma alboatrum, Lecanora marginata, Lecidea berengeriana, Miriquidica garovaglii, Pseudephebe minuscula, Sporastatia testudinea, and Xanthoparmelia wyomingica. Although a few of these are

known to be sensitive to pollution, the absence of the above species from the 1990 collections is most likely to be due to their preference for alpine habitats or at least higher elevations than were reached during the 1990 survey.

A few other species were collected along the West Fork trail in 1973 or 1983 but not found in 1990: Buellia disciformis, B. lakensis, Caloplaca ferruginea, Cladonia cenotea, C. pleurota, Lecanora impudents, Lecidea turgidula, Melanelia exasperatula, Rhizocarpon distinctum, and Usnea ceratina; most of these are inconspicuous species or ones that are easily confused with others that were collected in 1990.

Many additional taxa, not collected earlier, were found in 1990, which reflects the greater thoroughness of this most recent survey and the inclusion of extensive areas of cliffs and Pseudotsuga forest along the East Fork trail, which were not surveyed earlier.

## Comparison With Other Localities

Detailed comparisons between the lichen vegetation of the Mt. Baldy area and other localities in the southwestern United States are beyond the scope of this report. However, it can be stated that in general the Mt. Baldy area supports a lichen flora that is at least as diverse and well-developed as any comparable mountainous area in Arizona. The ecological distribution patterns (e.g., habitat or substrate preferences) of the species are quite typical, with a few possible exceptions discussed above (e.g., the restriction of Candelaria concolor to rock, and the scarcity of lichens on Populus). In comparison to other sites in the White Mountains, the most conspicuous difference is the apparent absence of species of Collema spp. from the Mt. Baldy Wilderness. No obvious signs of damaged or depauperate thalli that might be attributable to air pollution were observed.

## POLLUTION SENSITIVITY

There is information on the pollution senstivity of only a relatively limited number of the lichen taxa found in the Mt. Baldy Wilderness. Many of the lichens in this wilderness are saxicolous crustose taxa, on which few previous studies have been done. According to Hale (1982), saxicolous taxa, and crustose taxa in general, are likely to be fairly tolerant to pollution.

The notes below summarize what can presently be said about the pollution sensitivity of lichens in this Wilderness. With a few exceptions, the sensitivities attributed to these species are based on floristic studies which have not yet been confirmed by either transplant experiments or fumigation studies. Reports based on fumigation experiments are indicated by asterisks (*).

The sensitivity ratings are used below only as rough indications of the relative sensitivities expected. Although some of the cited authors, including Wetmore, have correlated their rating systems to particular concentrations of pollutants, the criteria and conditions used in the various studies are quite variable. Some authors, such as Hale (1982), did not explain the basis for their ratings. It should also be noted that sensitivity is frequently inferred on the basis of patterns observed in the field. Even where these patterns correspond to known pollutant gradients, the factors to which an appraently sensitive species responds cannot be known absolutely. Transplant experiments and much more extensive fumigation work with different air pollutants and the species found in this study are necessary.

### Sensitivity to Sulphur Dioxide

The major focus of most previous lichen/pollution studies has been on sulphur dioxide. The sensitivities of the following species are rated according to the system of Wetmore (1985): S = sensitive, I = intermediate, T = tolerant. Except for species specifically cited by Wetmore, these ratings as used here are relative, and do not correspond to particular concentrations of $SO_2$.

S Acarospora chlorophana--Hale (1982).

S Aspicilia alphoplaca--Marsh & Nash (1979)*

I Bryoria fuscescens--Wetmore (1985, 1987); Hawksworth & Rose (1970); Wirth & Türk (1975*).

T Buellia punctata--Wetmore (1985, 1987, 1988, 1989); Hawksworth & Rose (1970); Steubing (1974); DeWit (1976); Seaward (1987); Gilbert (1970b). A few authors considered it as slightly sensitive: Johnsen & Sochting (1973), DeSloover & LeBlanc (1968); Windler (1977).

S-I Caloplaca cerina--Wetmore (1985, 1987, 1988, 1989); Hawksworth & Rose (1970); LeBlanc & Rao (1975).

S Caloplaca trachyphylla--Marsh & Nash (1979)* (when wet).

S-I Candelaria concolor--Wetmore (1985, 1987, 1988); Hawksworth & Rose (1970), LeBlanc & Rao (1975), DeSloover & LeBlanc (1968), Skye (1968*). LeBlanc, et al. (1972) considered this species to be quite sensitive (affected by 13 ug/$m^3$ of $SO_2$.

I Candelariella vitellina--Wetmore (1985, 1987, 1988); DeSloover & LeBlanc (1968), DeWit (1976). Some reports (e.g., Follman, 1973; LeBlanc & Rao, 1975) treat this species among the more tolerant ones; other reports (e.g., Seitz, 1972) treat it as a relatively sensitive species.

I Cladonia coniocraea--Wetmore (1985, 1988, 1989); Seitz (1972); LeBlanc & Rao (1975) regarded this species as somewhat tolerant, while Schubert (1974*) found it to be somewhat sensitive.

S Cladonia deformis--Puckett, et al. (1973)*.

S-I Cladonia fimbriata--Wetmore (1985, 1988, 1989); according to LeBlanc, et al. (1972) it is sensitive to only 13 ug of $SO_2$.

S Dermatocarpon miniatum--Marsh & Nash (1979*).

S Diploschistes muscorum--Pisût (1962).

T-I Diplotomma alboatrum--Hawksworth & Rose (1970).

I Flavoparmelia caperata--Wetmore (1987, 1988, 1989); Hawksworth & Rose (1970); Baddeley, et al. (1973)*. However, several authors considered it to be somewhat closer to the sensitive end of the spectrum: DeSloover & LeBlanc (1968), Steubing (1974)*, Nash (1973)*, DeWit (1976).

S Flavopunctelia flaventior--Windler (1977).

S Flavopunctelia praesignis--Nash (1976*).

S Heterodermia hypoleuca--Windler (1977).

I-T Hypocenomyce scalaris--Intermediate according to Wetmore (1985, 1987) and Seitz (1972). However, Hawksworth & Rose (1970) placed this species in Zone 2, the second most tolerant of their five ranks, and other authors such as Skye (1968), Steubing (1974), Schubert (1974) and DeWit (1976) regarded it as quite tolerant.

S-I Hypogymnia farinacea--Kauppi & Mikkonen (1980).

I Hypogymnia physodes--Wetmore (1988, 1989); DeSloover & LeBlanc (1968); Marti (1983*); many other reports, some regarding it as tolerant-intermediate (Johnsen & Sochting, 1973, LeBlanc & Rao, 1975, Wirth & Turk, 1975*), others as sensitive (Seitz, 1972, Pisut, 1962, DeWit, 1976*).

S Hypogymnia tubulosa--Kauppi & Mikkonen (1980); Trass (1973)

I Imshaugia aleurites--Wetmore (1987, 1988, 1989).

I Lasallia pustulata--Wirth & Turk (1974*).

T Lecanora muralis--Wetmore (1985, 1987); Schubert (1974); Fields & St. Clair (1984); however, Seaward (1976) found it to be abnormal in anatomy in polluted areas, and Marsh & Nash (1979*) found it to be somewhat sensitive.

I Lecanora saligna--Wetmore (1985, 1987, 1988). LeBlanc & Rao (1975) placed this species in the most tolerant of their five ranks.

I Lecanora symmicta--Wetmore (1987, 1988); DeWit (1976); Wirth & Turk (1974*); LeBlanc & Rao (1975) regarded it as somewhat sensitive.

S Lecidella euphorea--Skye (1968); LeBlanc, et al. (1972).

T Lepraria incana--Hawksworth & Rose (1970), LeBlanc & Rao (1975), Skye (1968), De Wit (1975), Follmaan (1973), Johnsen & Sochting (1973), Seitz (1972), DeSloover & LeBlanc (1968), Jurging (1971, 1972).

I Melanelia exasperatula--Skye (1968); DeSloover & Leblanc (1968); Hawksworth & Rose (1970); LeBlanc & Rao (1975).

S Nephroma parile--Skye (1968).

S Pannaria spp.--Hawksworth & Rose (1970).

I-T Parmelia saxatilis--Intermediate according to Wetmore (1985, 1987). Some authors, including Hawksworth & Rose (1970), Seitz (1972), and Baddeley, et al. (1973*), regarded this species as at least moderately tolerant. Others, such as DeSloover & LeBlanc (1968), Wirth & Türk (1975*) and DeWit (1976) place this species somewhat closer to the sensitive end of the spectrum.

I-T Parmelia sulcata--Intermediate to tolerant according to Wetmore (1985, 1987, 1988); Hawksworth & Rose (1970), Johnsen & Sochting (1973), Wirth & Türk (1975*). LeBlanc & Rao (1975) treated this as a tolerant species. On

the other hand, workers suggesting that it is fairly sensitive include Pisut (1962), Skye (1968*), DeWit (1976*), Windler (1977) and Taylor & Bell (1983).

I-T Parmeliopsis ambigua--Intermediate according to Wetmore (1985, 1987). Hawksworth & Rose (1970), DeSloover & LeBlanc (1968) and LeBlanc & Rao (1975) place this species somewhat closer to the tolerant end of the spectrum, and Wetmore (1988b) suggested that it may even be increasing in abundance in polluted areas. On the other hand, DeSloover & LeBlanc (1968) and Trass (1973) considered it to be fairly sensitive.

I Parmeliopsis hyperopta--Wetmore (1987).

S Peltigera aphthosa--Atlas & Schofield (1976); Fritz-Sheridan (1985*)(nitrogen fixation inhibited by $H_2SO_4$).

T? Peltigera canina--Likely to be "least sensitive" according to Hale (1982), but found only in the "normal zone" according to Skye (1968), and nitrogen fixation inhibited by $H_2SO_4$ according to Henriksson & Pearson (1981)*.

S Peltigera polydactyla--Fritz & Sheridan (1985*)(nitrogen fixation inhibitted by $H_2SO_4$).

I Physcia aipolia--Intermediate according to Wetmore (1985, 1987) and Hawksworth & Rose (1970), but DeSloover & LeBlanc (1968) and LeBlanc & Rao (1975) considered it somewhat sensitive.

I Physcia caesia--DeSloover & LeBlanc (1968); DeWit (1976).

T Physcia dubia--Wetmore (1985); Johnsen & Sochting (1973) considered it as being more intermediate.

I Physcia stellaris--Wetmore (1985, 1987, 1988, 1989); LeBlanc & Rao (1975), DeSloover & LeBlanc (1968); Marti (1983). However, LeBlanc, et al. (1972) regarded it as somewhat sensitive, and Beekley & Hoffman (1981) considered it to be somewhat tolerant.

I Physconia detersa--Wetmore (1989), DeSloover & LeBlanc (1968), LeBlanc & Rao (1975) and Hoffmman (1974), Beekley & Hoffman (1981)*. Most North American reports on "Physcia grisea" are probably based on P. detersa.

I Physconia grisea--DeWit (1976), Johnsen & Sochting (1973); Pisut (1962) regarded it as an indicator of the "relatively unpolluted zone."

I Punctelia subrudecta--Wetmore (1987, 1989); Seitz (1972); DeWit (1976); Windler (1977); Baddeley, et al. (1973*); somewhat tolerant according to Hawksworth & Rose (1970).

S Ramalina pollinaria--Wetmore (1987, 1989); Hawksworth & Rose (1970).

T Rhizocarpon geographicum--Ranft (1971) ("a widespread smoke species"; Schubert (1974); Wirth & Turk (1974*) considered it as intermediate.

S Rhizoplaca chrysoleuca--Hale (1982).

S Rhizoplaca melanophthalma--Hale (1982); Marsh & Nash (1979*).

T-I Tuckermannopsis pinastri--LeBlanc & Rao (1975).

S-I Usnea ceratina--Baddeley, et al. (1973*); Hawksworth & Rose (1970).

S-I Usnea filipendula--Wetmore (1987), DeSloover & LeBlanc (1968), Marti (1983)*. However Hawksworth & Rose (1970 regarded it as very sensitive.

S-I Usnea hirta--Wetmore (1989); Eversman (1978*); Johnson (1979*) reported it as one of the most sensitive speci (affected by only 8 ug/$m^3$).

S-I Usnea subfloridana--Wetmore (1987); Baddeley, et al. (1973*) and Hawksworth & Rose (1970) regarded it as intermediate; Trass (1973) considered it to be sensi.

S Xanthoparmelia cumberlandia--Hale (1982).

I Xanthoria candelaria--Wetmore (1985); DeSloover & LeBla (1968). Hawksworth & Rose (1970) placed this species in Zone 2 (somewhat tolerant).

S Xanthoria elegans--Hale (1981).

S-I Xanthoria fallax--Wetmore (1985, 1987, 1988); DeSloover & LeBlanc (1968). Both Marti (1983*) and LeBlanc & Rao (1975) placed this species in the most sensitive of their five ranks, and Skye (1968*) also considered it sensitive.

I Xanthoria polycarpa--Intermediate according to Wetmore (1985, 1987, 1988); Skye (1968); and Hawksworth & Rose (1970). However, LeBlanc & Rao ranked this species as 5 (most sensitive), and DeSloover & LeBlanc gave it a toxiphoby of 7 (fairly sensitive).

## Sensitivity to Oxidants

The sensitivities of the following species to oxidants are ranked according to a modification of the system of Sigal & Nash (1983): S = very sensitive, S-I = sensitive, I-T = moderately tolerant, T = tolerant.

S-I *Cladonia* spp.--Sigal & Nash (1983).

I-T *Melanelia subolivacea*--Nash & Sigal (1980*); Sigal & Nash (1983).

S *Parmelia sulcata*--Nash & Sigal (1979*, 1980*); Sigal & Nash (1983).

S *Peltigera canina*--Sigal & Nash (1983).

S-I *Peltigera rufescens*--Sigal & Nash (1983).

S *Phaeophyscia ciliata*--Sigal & Nash (1983).

T *Physcia biziana*--Sigal & Nash (1983).

S *Rhizoplaca chrysoleuca*--Nash (1976) ($NO_2$).

S *Usnea* spp.--Sigal & Nash (1983).

S *Usnea cavernosa*--Nash (1976*)($NO_2$).

T *Xanthoria fallax*--Sigal & Nash (1983).

T-I *Xanthoria polycarpa*--Sigal & Nash (1983).

## Sensitivity to Fluorides

T = tolerant, S = sensitive, I = intermediate.

S *Caloplaca cerina*--LeBlanc, et al. (1972).

I *Candelariella vitellina*--Tolerant according to Perkins & Millar (1987), but sensitive according to LeBlanc, et al. (1972b).

S-I *Hypogymnia physodes*--DeWit (1976), Horntvedt (1976), Schönbeck & Van Haut (1971), Steubing (1974).

S *Lecanora polytropa*--Perkins & Millar (1987).

S-I *Parmelia saxatilis*--Steubing (1974); DeWit (1976*).

S-I *Parmelia sulcata*--Perkins & Millar (1987); LeBlanc, et al. (1972b); Steubing (1974*).

T *Parmeliopsis ambigua*--Horntvedt (1976).

S-I Physcia dubia--LeBlanc, et al. (1972b).

I Rhizocarpon geographicum--Sensitive according to Martin & Jacquard (1968), but tolerant according to Böritz & Ranft (1972).

Other Species Likely to be Sensitive to Various Pollutants

Based on their growth forms or the known sensitivites of other members of the genus, several other species can be expected to be at least moderately sensitive to various pollutants:

Evernia divaricata

Heterodermia spp.

Leptogium spp.--Nitrogen fixing.

Nephroma spp.--Nitrogen fixing.

Ochrolechia spp.

Pertusaria spp.

Pseudephebe spp.--Observations made during a recent study (Ryan, 1990) show that although P. minuscula is still abundant at one site in the San Gabriel Wilderness, thalli of this species there are damaged, presumably due to oxidant pollution.

Pseudevernia spp.

Sticta spp.--Nitrogen fixing; with "breathing pores".

Umbilicaria spp.--According to Ranft (1971), U. cylindrica and U. polyphylla are "sligtly sensitive" to $SO_2$, and according to Sigal (in Lawrey, 1984), U. mammulata showed necrosis when treated with simulated acid rain. Likely to be sensitive because of the foliose growth form.

## CONCLUSIONS

The Mt. Baldy Wilderness presently supports a very rich and rather luxuriant flora, including many species of known or likely sensitivity to pollutants. No obvious signs of possible pollution-induced damage to the lichens were observed. With a few possible exceptions, no evidence of major differences in the lichen flora in comparison to the earlier collections or to other mountainous areas in Arizona were found. Based on the data presented here, little can be concluded about the present level of air pollution in this Wilderness, except that the presence of several species of known sensitivity and the lack of obvious symptoms of pollution damage to the lichens indicates that the present pollution is not severe. However, these data (especially the quantitative sampling) provide baseline information for future monitoring of changes in the air quality in this Wilderness. As detailed descriptions of the lichen vegetation of other areas in in the Southwest become available, it should be more feasible to draw conclusions about air quality from comparative studies.

If conditions in the Mt. Baldy Wilderness deteriorate in the future due to influxes of sulfur dioxide, the foliose or fruticose lichens that would be most likely to show visual injury or reduced populations fairly soon are the following: Acarospora chlorophana, Aspicilia alphoplaca, Bryoria fuscescens, Caloplaca trachyphylla, Cladonia deformis, Dermatocarpon miniatum, Evernia divaricata, Flavopunctelia spp., Heterodermia spp., Hypogymnia tubulosa, Leptogium spp., Nephroma spp., Pannaria spp., Peltigera spp., Pseudevernia intensa, Ramalina pollinaria, Rhizoplaca spp., Sticta beauvoisii, Umbilicaria spp., Usnea spp., Xanthoparmelia spp., and Xanthoria spp. Several of these, as well as Parmelia spp. are also likely to be noticeably affected by increases in other types of pollutants. A few crustose species (e.g., Caloplaca cerina, Diploschistes muscorum, and species of Ochrolechia and Pertusaria) may also become less abundant, although damage symptoms may not be very apparent.

## RECOMMENDATIONS FOR FUTURE MONITORING

Although complete re-surveying of the lichen flora will probably not be necessary at least for another 10-15 years, repetition of the quantitative sampling at intervals of about 5 years is desirable, to detect possible shifts in the the relative abundance of lichen species.

### Quantitative Sampling

New quantiative sampling should be done in the same general localities and habitats as those reported here, following the exact procedures described in the Methods section. In comparing the results to those presented in Tables 1-5 in this report, major (e.g., 25% or more) changes in the cover or frequency of particular species (especially ones known to be especially

sensitive or especially tolerant) may be significant, especially if the trend continues or increases after several re-samplings. In the case of the samples on Pseudotsuga, a major shift in the distribution of species relative to height of compass direction may be significant (e.g., pollution tends to cause some sensitive species to shift downward on the trunk, where the pollution effects are less severe).

It must be remembered that minor variations (mostly due to sampling errors) can be expected, and if some species reported in Tables 1-5 (especially the less common ones) are not found within the plots, it should be noted whether or not they occur in the same area but outside the plots. Voucher specimens of species not identifiable in the field should be collected and then identified in the lab (with help from a competent lichenologist if the identity is very uncertain and critical).

Permanent Transects and Quadrats

It is also desriable to establish permanent transects on trees and quadrats on rock in the near future, using procedures such as those used in our recent studies in California wildernesses. The present lichen vegetation in the Mt. Baldy Wilderness is developed to a degree that would make such monitoring approaches quite feasible and potentially very useful. Transects on trees should concentrate on the following taxa, which are abundant, known or likely to be sensitive to one or more pollutants, and relatively easy to recognize and measure: Bryoria fuscescens, Flavopunctelia spp., Pseudevernia intensa, Usnea spp. (especially U. ceratina and U. hirta), and possibly Parmelia sulcata. Likewise, the following taxa would be the most suitable ones for quadrats on rock, in areas where they are locally abundant: Acarospora chlorophana, Dermatocarpon miniatum, Ramalina pollinaria, Rhizoplaca chrysoleuca, and Xanthoria elegans. Quadrats with species of Nephroma or Peltigera (especially P. aphthosa) might also be worthwhile, although there may be some changes over time due to the soil or moss (with the attached lichens) falling off the rock.

Element Analysis

In addition, when it becomes feasible, the element analysis of the lichens collected for that purpose during the present study should be undertaken. Element analyses should provide a basis for comparisons with other parts of the country (having greater or lesser exposure to various pollutants) where element data is available for the same lichen taxa (e.g., the Chiricahuas, analyzed by Wetmore, 1987), and with the generalized "background" and "enhanced" concentration ranges given by Nieboer (1978). They may also yield some information on differences in element loadings in different parts of the Mt. Baldy Wilderness correlated with greater proximity to roads or other localized pollution sources.

The analyses performed by Dr. Phil Rundel at UCLA for our studies in California wildernesses included 26 "heavy metals," but not sulfur. The preliminary results from those wildernesses show several things: 1) at least 3, and preferrably more, replications are needed for each sample, and even then there is considerable variability within the samples; 2) different species from the same site (especially if different in growth form or substrate) often show extremely different concentrations of some elements; 3) comparisons among wildernesses or other study areas, and among sites in a given wilderness, for the same species, often show remarkable differences in mean concentrations of various metals, that correlate with exposure to larger amounts of pollution.

In the Mt. Baldy Wilderness, the fruticose, corticolous species already sampled for eventual element analysis (Bryoria fuscescens, Pseudevernia intensa and Usnea spp.) are probably the best ones for that purpose. However, information on foliose or umbilicate, rock-inhabiting species (especially Xanthoparmelia cumberlandia) might also be useful in the future.

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Figure 1. Location of Mt. Baldy Wilderness Area, Apache Co. Arizona.

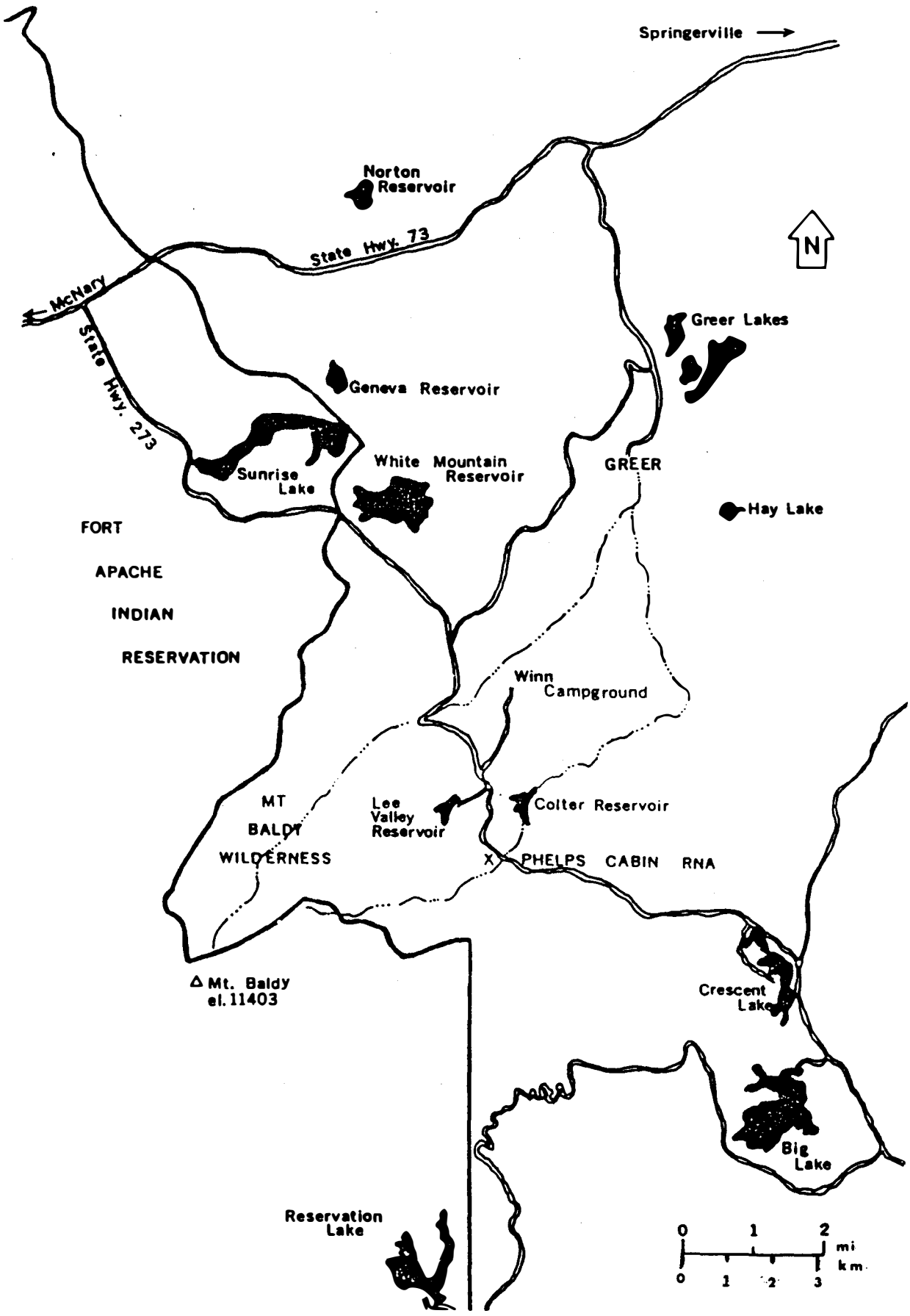
Springerville
Norton Reservoir
State Hwy. 73
McNary
State Hwy. 273
N
Greer Lakes
Geneva Reservoir
Sunrise Lake
White Mountain Reservoir
GREER
Hay Lake
FORT
APACHE
INDIAN
RESERVATION
Winn Campground
MT
BALDY
WILDERNESS
Lee Valley Reservoir
Colter Reservoir
PHELPS CABIN RNA
Mt. Baldy el. 11403
Crescent Lake
Big Lake
Reservation Lake
0 1 2 mi
0 1 2 3 km

Figure 2. Mt. Baldy Wilderness Area, Arizona, showing the main lichen collecting localities (1-7) described in Appendix A. Localities 5 and 6 include extensive areas along the East Fork and West Fork trails, respectively.

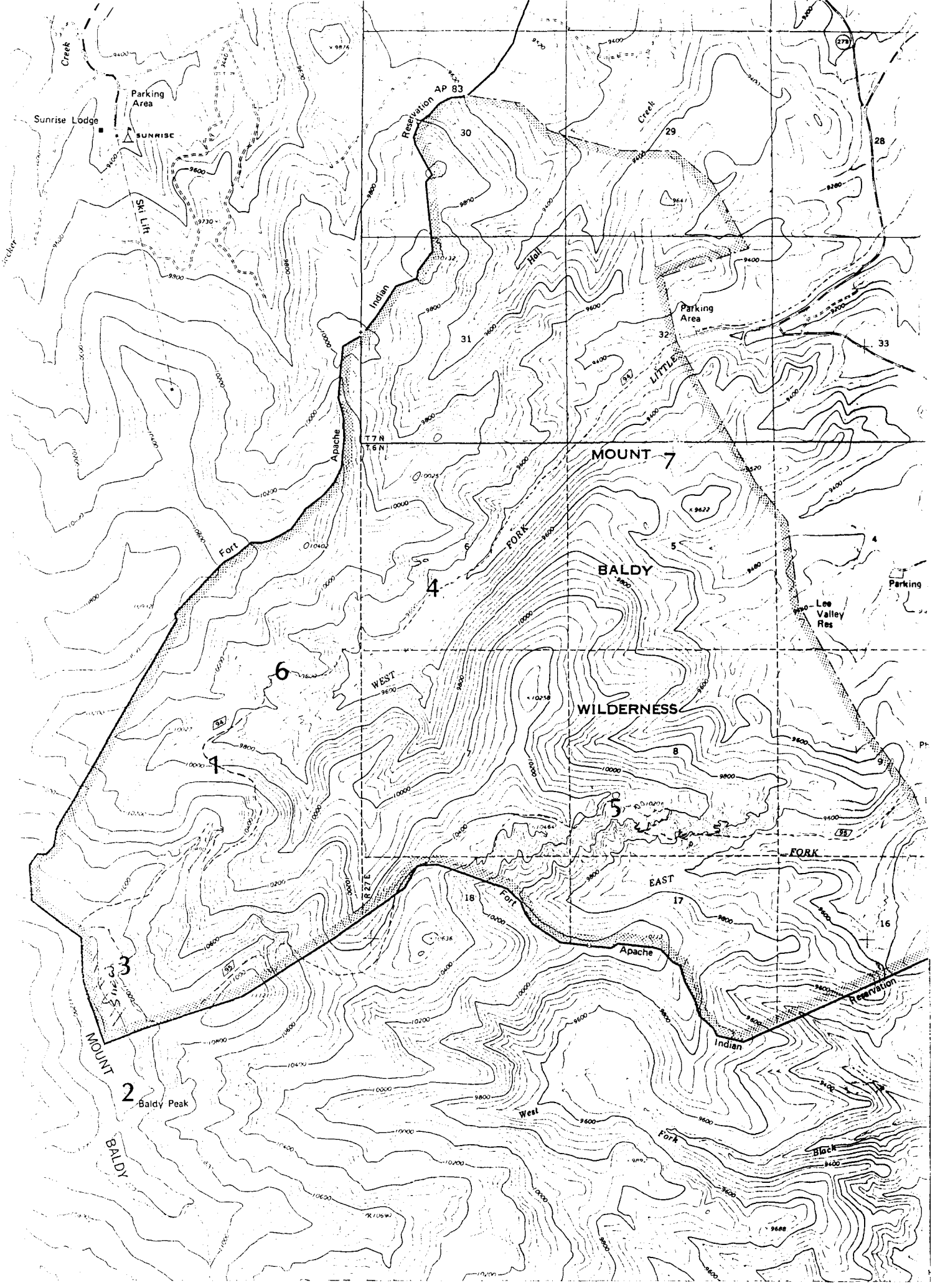
Parking Area
Sunrise Lodge
SUNRISE
Ski Lift
Reservation
AP 83
Creek
Hall
Indian
Parking Area
LITTLE
Apache
T7N
T6N
MOUNT 7
FORK
BALDY
Lee Valley Res
WEST
WILDERNESS
EAST
Fort
Apache
Indian
Reservation
MOUNT BALDY
Baldy Peak
West
Fork
Black

Table 1. Mean per cent lichen cover (n=15) on the trunks of *Pseudotsuga menziesii* at the base and d.b.h. (1.5 m) for E, S, W and N exposures along the East Fork Trail (Little Colorado River)

| Lichen species | Tree Base | | | | D.B.H. | | | |
|---|---|---|---|---|---|---|---|---|
| | E | S | W | N | E | S | W | N |
| *Cladonia coniocraea*[1] | 0.7 | 0.1 | 0.9 | 2.5 | | | | |
| *Cladonia pyxidata* | 0.1 | | | 0.5 | | | | |
| *Flavoparmelia soredica* | | | 0.1 | | | 0.2 | 0.7 | 1.1 |
| *Hypogymnia austerodes* | | | | | | | | 0.7 |
| *Hypogymnia bitteri* | | | | | 0.1 | | | 0.2 |
| *Hypotrachyna laevigata* | | | | | 0.2 | | 0.1 | 0.4 |
| *Imshaugia aleurites* | | | | | | | 0.1 | |
| *Lecanora saligna* | 0.1 | 0.1 | | 0.3 | | | | |
| *Lecanora "subfusca"* | 0.1 | | | 0.1 | | | | |
| *Lecidella euphorea*[2] | | | | 0.7 | | | | |
| *Lepraria "incana"*[3] | 3.5 | 0.1 | 0.7 | | | | | 0.1 |
| *Parmelia sulcata* | | | 0.6 | 0.5 | 0.1 | | 0.8 | 2.3 |
| *Parmeliopsis ambigua* | 3.3 | 1.7 | 2.0 | 4.4 | | | | |
| *Parmeliopsis hyperopta* | 1.3 | | | 1.9 | | | | |
| *Pertusaria wulfenoides* | | | | | 0.1 | | 0.1 | 1.9 |
| *Pseudevernia intensa* | | | | | 0.2 | | | 0.1 |
| *Tuckermannopsis fendleri*[4] | | | | | | | | 0.1 |
| *Tuckermannopsis pinastri* | 0.4 | | | 0.4 | | | | |
| *Usnea "subfloridana"*[5] | | | 0.1 | 0.1 | 1.5 | 0.6 | 2.2 | 4.4 |
| **Total Cover** | 10.1 | 2.0 | 4.4 | 11.4 | 2.2 | 0.8 | 4.0 | 11.3 |

[1] plus *C. fimbriata* and *C. subradiata*.

[2] plus *Buellia erubescens* and *B. punctata*.

[3] mixture of species.

[4] plus *Cetraria coralligera*.

[5] including *U. lapponica* sensu lato.

Table 2. Frequency of occurrence of lichens on the lower 2m of trunks of Pseudotsuga menziesii based on 15 randomly selected trees along the East Fork Trail (Little Colorado River).

| Lichen Species | Frequency (%) |
|---|---|
| Bryoria fuscescens | 20 |
| Cladonia coniocraea | 53 |
| Cladonia pyxidata | 40 |
| Flavoparmelia soredica | 73 |
| Hypogymnia austerodes | 60 |
| Hypogymnia bitteri | 13 |
| Hypogymnia physodes | 7 |
| Imshaugia aleurites | 53 |
| Lecanora saligna | 27 |
| Lecanora "subfusca" | 20 |
| Lecidella euphorea | 20 |
| Lepraria incana | 20 |
| Ochrolechia pallescens | 7 |
| Pachyspora verrucosa | 7 |
| Parmelia sulcata | 73 |
| Parmeliopsis ambigua | 100 |
| Parmeliopsis hyperopta | 27 |
| Pertusaria wulfenoides | 60 |
| Pseudevernia intensa | 47 |
| Tuckermannopsis fendleri | 20 |
| Tuckermannopsis pinastri | 40 |
| Usnea cavernosa | 7 |
| Usnea hirta | 7 |
| Usnea subfloridana group | 100 |
| Xanthoparmelia cumberlandia | 7 |

Mean No. of species/tree = 9.1

Table 3. Frequency by tree (n=20) and by branches/tree for three common fruticose lichens occurring on Picea englemannii in a stand (847 tree·ha$^{-1}$) adjacent the East Fork of the Little Colorado River. Only branches with 4 m of the ground were examined; one tree had no branches within this interval.

| Lichen Species | Tree Frequency | Branch Frequency |
|---|---|---|
| Pseudevernia intensa | 90% | 48.9 |
| Usnea cavernosa | 60% | 18.4 |
| Usnea "comosa"[1] | 95% | 69.0 |

[1] including U. hirta, U. lapponica sensu lato, and U. subfloridana (all with short, tufted thalli).

Table 4. Percent presence of lichen species on cedar fenceposts along the boundary of the Mt. Baldy Wilderness, near Phelps Cabin (East Fork of Little Colorado River), based on 20 randomly selected cedar fenceposts (10 south of gate, near creek, and 10 north of gate, in a drier area).

| Species | South of Gate | North of Gate | Total |
|---|---|---|---|
| Caloplaca cerina | 05 | 05 | 20 |
| Caloplaca microphyllina | 35 | 20 | 55 |
| Candelariella sp. | 15 | 00 | 15 |
| Cyphelium tigillare | 40 | 35 | 75 |
| Flavoparmelia sp. | 00 | 05 | 05 |
| Flavopunctelia soredica | 10 | 20 | 30 |
| Hypocenomyce sp. | 05 | 00 | 05 |
| Hypotrachyna pulvinata | 05 | 00 | 05 |
| Lecanora caesiorubella | 00 | 05 | 05 |
| Lecanora hageni | 05 | 05 | 10 |
| Lecanora saligna | 40 | 20 | 60 |
| Lecanora sp. | 15 | 00 | 15 |
| Lecidea sp. | 00 | 05 | 05 |
| Lecidella sp. | 05 | 10 | 10 |
| Melanelia subolivacea | 05 | 10 | 15 |
| Physcia sp. | 10 | 10 | 20 |
| Physconia detersa | 15 | 05 | 20 |
| Pseudevernia intensa | 05 | 10 | 15 |
| Punctelia subrudecta | 00 | 05 | 05 |
| Rinodina sp. | 25 | 10 | 35 |
| Trapeliopsis flexuosa | 05 | 05 | 10 |
| Usnea spp. (tufted) | 40 | 40 | 80 |
| Xanthoparmelia sp. | 10 | 00 | 10 |
| Xanthoria fallax | 20 | 05 | 25 |
| Xylographa sp. | 05 | 00 | 05 |

Table 5. Mean lichen cover (n=20) and frequency per quadrat on a rock scree near the East Fork of the Little Colorado River.

| Lichen Species | Cover (%) | Frequency (%) |
|---|---|---|
| *Acarospora fuscata* | 0.2 | 30 |
| *Aspicilia cinerea* | 2.6 | 50 |
| *Lecanora intricata* | 0.05 | 5 |
| *Lecanora mazatzalensis* | 0.3 | 60 |
| *Lecidea* spp. (brown) | 18.2 | 85 |
| *Lecidea moreliensis* | 1.4 | 10 |
| *Lepraria "incana"* | 0.05 | 20 |
| *Rhizocarpon geographicum* s.l. | 3.0 | 90 |
| *Xanthoparmelia cumberlandia* | 5.6 | 85 |

# APPENDIX A:

## COLLECTING LOCALITIES

(All Apache Co., Arizona)

1. Trail to Mt. Baldy from Sheep's Crossing (along West Fork of Little Colorado River). 33°57'N, 109°32'W. 2987-3139 m (9800-10,300 ft). Nash, 25 July 1973.

2. Summit of Mt. Baldy ("Baldy Peak" on labels). 33°54'N, 109°33'W. 3533 m (11,590 ft). Nash, 28 Sept. 1974.

3. East slope of Mt. Baldy. 33°54'N, 109°32'W. 3383 m (11,100 ft). Nash, 28 Sept. 1974.

4. Trail from Sheep's Crossing towards Mt. Baldy (along W. fork of Little Colorado). 33°57'N, 109°31'W. 2870 m. Nash, 8 Oct. 1983.

5. Trail from Phelps Cabin towards Mt. Baldy (along E. Fork of Little Colorado). 33°55'30"N, 109°29'30"W to 33°54'30"N, 109°33'45"W. Elevation 2950-3340 m (9700-10960 ft). Picea. Nash, Ryan & Davis, 28 & 30 June, 1-2 July 1990; Nash, 29 September 1990.

6. Trail from Sheep's Crossing towards Mt. Baldy (along W. Fork of Little Colorado). 33°57'30"N, 109°31'W to 33°55'15"N, 109°33'15"W. Elev. 2900-3265 m (9400-10720 ft). Pseudotsuga, Abies. Nash, Ryan & Davis, 29 June 1990.

7. Trail from W. Fork of Little Colorado to Phelps Cabin. 33°57'N, 109°31'W. Elevation 2850 m (9250 ft). Picea. Nash, 30 September 1990.

APPENDIX B:

LIST OF LICHEN SPECIES IN THE MT. BALDY WILDERNESS

The numbers 1-7 after species names refer to the collecting localities described in Appendix A. Lists of species and voucher specimens for each locality are given in Appendix C.

* means new to Arizona.
** means new to North America.

Acarospora chlorophana (Wahlenb. ex Ach.) Massal.--On rock, 2, 5, 6.

Acarospora fuscata (Nyl.) Arnold--On rock, 5.

Acarospora cf. schleicheri (Ach.) Massal.--On rock, 5.

Acarospora spp. (brown thallus)--On rock, 5, 6.

*Amygdalaria elegantior (Magnusson) Hertel & Brodo--On rock, 2.

Aspicilia alphoplaca (Wahlenb. in Ach.) Poelt & Leuck.--On rock, 5.

Aspicilia cinerea (L.) Körber--On rock, 1, 5.

Aspicilia spp.--On rock, 5.

Bellemerea alpina (Sommerf.) Clauz. & Roux--On rock, 6.

Bacidia sp.--On Populus, 5. Thallus whitish; apothecia black; hypothecium red-brown; spores 35-40 x 1.5 um.

*Bellemerea cinereorufescens (Ach.) Clauz. & Roux--On rock, 5.

*Bryoria fuscescens var. positiva (Gyelnik) Brodo & D. Hawksw.--On Picea, 1, 3, 5, 6; on Abies, 6; on trunk of Pseudotsuga, 5.

Buellia disciformis (Fr.) Mudd--On wood, 1.

Buellia erubescens Arnold--On Picea, 1; on wood at base of Pinus strobiliformis, 5; on Pseudostsuga, 5.

*Buellia immersa Lynge--On rock, 5.

*Buellia lacteoidea B. de Lesd.--On rock, 2.

*Buellia "lakensis" Egan ined.--On rock, 4.

*Buellia leptocline (Flotow) Massal.--On rock, 5.

Buellia novomexicana B. de Lesd.--On rock, 1, 5.

Buellia punctata (Hoffm.) Massal.--On Pseudotsuga, 5.

Buellia semitensis Tuck.--On rock, 5.

**Buellia subdisciformis (Leight.) Vainio--On rock, 5.

Buellia sp.--On soil, 6. Thallus sorediate. Apparently undescribed.

Buellia sp.--On Abies, 4; on Pseudotsuga, 5. Spores pseudomuriform, smaller than those of any species reported from North America; possibly undescribed.

Buellia spp.--On rock, 5.

*Caloplaca arenaria (Pers.) Müll. Arg.--On rock, 5.

Caloplaca cerina (Ehrh. ex Hedw.) Th. Fr.--On Populus, 5.

Caloplaca ferruginea (Huds.) Th. Fr.--On Abies, 1.

Caloplaca microphyllina (Tuck.) Hasse--On wood (fencepost), 5.

Caloplaca pelodella (Nyl.) Hasse--On rock, 5.

Caloplaca saxicola (Hoffm.) Nordin--On rock, 5.

*Caloplaca sipeana Magnusson--On rock, 5.

Caloplaca trachyphylla (Tuck.) Zahlbr.--On rock, 5.

Candelaria concolor (Dickson) B. Stein--On rock, 5.

Candelariella vitellina (Hoffm.) Muell. Arg.--On rock, 2, 5, 6.

Candelariella rosulans (Müll. Arg.) Zahlbr.--On rock, 5.

Candelina submexicana (B. de Lesd.) Poelt--On rock, 5.

Catapyrenium lachneum (Ach.) R. Sant.--On soil over rock, 5.

Catapyrenium zahlbruckneri (Hasse) Thomson--On rock, 6.

Cetraria coralligera (W. Weber) Hale--On Pseudotsuga, 5.

Cetraria? sp.--On Picea twigs, 4.

Chaenotheca furfuracea (L.) Tibell--On rock, 6.

Cladonia bacillaris Nyl.--On base of Pseudotsuga, 1, 5; on base of Picea, 5; on rotten wood, 5.

Cladonia cariosa (Ach.) Sprengel--On soil, 5; on rotten wood, 7.

Cladonia cenotea (Ach.) Schaerer--On moss, 5; on rotten wood, 4, 6, 7.

Cladonia cervicornis ssp. verticillata (Hoffm.) Ahti--On soil, 5.

Cladonia chlorophaea (Flörke ex Sommerf.) Sprengel--On base of Abies, 1; on moss and detritus, 5. Some material contains atranorin only; the rest also contain fumarprotocetraric acid.

Cladonia coccifera (L.) Willd.--On soil, 5.

Cladonia coniocraea auct.--On wood, 1; on detritus, 3; on base of Pseudotsuga, 5.

Cladonia deformis (L.) Hoffm.--On rotten wood, 1, 5, 7; on soil, 5.

Cladonia fimbriata (L.) Fr.--On Pseudotsuga, 5; on soil and moss, 6, 7

Cladonia glauca Flörke--On rotten wood, 7

*Cladonia macrophyllodes Nyl.--On soil, 4, 5.

*Cladonia ochrochlora Flörke--On decaying moss, 5.

*Cladonia pleurota (Flörke) Schaerer--On wood, 3, 4.

*Cladonia pocillum (Ach.) O. Rich--On soil, 5.

*Cladonia polycarpioides f. epiphylla (Robb.) Thomson--On soil, 5.

Cladonia pyxidata (L.) Hoffm.--On soil among moss, 1, 5, 6; on base of Pseudotsuga, 5.

Cladonia subradiata (Vainio) Sandst.--On base of Pseudotsuga, 5.

Cladonia sulphurina (Michaux) Fr.--On decaying wood, 4, 5, 7.

Cladonia spp. (mostly basal squamules)--On wood, 1, 6; on shelf fungus, 5; on base of Pseudotsuga, 5; on soil or moss, 5, 6.

Cyphelium tigillare (Ach.) Ach.--On wood (including fenceposts), 5.

Dermatocarpon intestiniforme (Koerber) Hasse--On rock, 5.

Dermatocarpon miniatum (L.) Mann--On rock, 5.

*Dermatocarpon reticulatum Magnusson--On rock, 5.

Dimelaena oreina (Ach.) Norman--On rock, 5.

Diploschistes muscorum (Scop.) R. Sant.--On detritus, 2.

Diploschistes scruposus (Schreber) Norman--On rock, 5.

Diplotomma alboatrum (Hoffm.) Flotow--On rock, 2.

Evernia divaricata (L.) Ach.--On Picea, 1, 5, 6.

Flavoparmelia caperata (L.) Hale--On Pseudotsuga, 5; on wooden fencepost, 5.

Flavopunctelia flaventior (Stirton) Hale--On Picea, 1, 5; on rock, 5.

Flavopunctelia praesignis (Nyl.) Hale--On Picea, 5.

Flavopunctelia soredica (Nyl.) Hale--On trunk of Pseudotsuga, 5; on Picea, 5; on rock, 5.

Heterodermia cf. casarettiana (Massal.) Trevisan--On moss over boulders and cliffs, 5; on Pseudotsuga, 5; on Populus, 5. May be H. obscurata.

Heterodermia hypoleuca (Muhl) Trevisan--On mossy rock, 5; on Pseudotsuga, 5.

Heterodermia sp. (sorediate)--On exposed boulders, 5.

Hypocenomyce anthracophila (Nyl.) P. James & G. Schneider--On Pseudotsuga, 5.

Hypocenomyce friesii (Ach. in Liljeblad) P. James & G. Schneider--On trunk of Pseudotsuga, 5.

Hypocenomyce scalaris (Ach. ex Liljeblad) M. Choisy--On trunk of Pseudotsuga, 5.

*Hypocenomyce xanthococca (Sommerf.) P. James & G. Schneider--On wood, 5 (pycnidial form); on Pinus strobiliformis, 5 (fertile form).

*Hypogymnia austerodes (Nyl.) Räsänen--On detritus, 2(?); on trunk of Pseudotsuga, 5; on Picea, 5, 6.

Hypogymnia bitteri (Lynge) Ahti--On trunk of Pseudotsuga, 5, 6; on Picea, 5, 6, 7.

*Hypogymnia farinacea Zopf--On Picea, 6

*Hypogymnia metaphysodes (Asah.) Rass.--On Picea, 5, 6.

Hypogymnia physodes (L.) Nyl.--On Pseudotsuga, 3, 5, 6; on Picea, 5, 6, 7.

*Hypogymnia tubulosa (Schaerer) Havaas--On Picea, 5, 6.

Hypogymnia sp.--On Picea, 1, 4; on Abies, 1; on Pseudotsuga, 1.

Hypotrachyna laevigata (Sm.) Hale--On trunk of Pseudotsuga, 5.

Hypotrachyna polydactyla (Krog & Swinscow) Nash--On Pseudotsuga, 5.

Hypotrachyna pulvinata (Fée) Hale--On Picea, 1, 5, 6, 7; on Pseudotsuga, 3.

*Hypotrachyna rockii (Zahlbr.) Hale--On Abies, 5.

Imshaugia aleurites (Ach.) S. F. Meyer--On trunk of Pseudotsuga, 5.

Imshaugia placorodia (Ach.) S. F. Meyer--On trunk of Pseudotsuga, 5.

Lasallia papulosa (Ach.) Llano--On rock, 5.

Lasallia pensylvanica (Hoffm.) Llano--On rock, 5.

*Lasallia pustulata (L.) Mérat--On rock, 5.

Lecanora argopholis (Ach.) Ach.--On rock, 5.

Lecanora cenisia Ach.--On rock, 1, 5, 6.

*Lecanora demissa (Flotow) Koerber--On rock, 5.

Lecanora impudens Degel.--On Abies, 1; partly reported as Ochrolechia androgyna.

*Lecanora intricata (Ach.) Ach.--On rock, 5.

**Lecanora laatokkaensis (Räsänen) Poelt--On rock, 5.

Lecanora marginata (Schaerer) Hertel & Rambold--On rock, 2.

**Lecanora "mazatzalensis" Ryan & Nash ined.--On rock, 5.

Lecanora muralis (Schreber) Rabenh.--On rock, 5, 6.

*Lecanora cf. opiniconensis Brodo--On rock, 5.

Lecanora polytropa (Hoffm.) Rabenh.--On rock, 1, 2, 5; on wood, 5.

Lecanora rupicola (L.) Zahlbr.--On rock, 2, 5.

Lecanora saligna (Schrader) Zahlbr.--On base of Pseudotsuga, 5; on base of Pinus strobiliformis, 5; on wood (fencepost), 5; on Abies, 5.

Lecanora symmicta (Ach.) Ach.--On Picea twigs, 4, 7.

Lecanora sp. (L. subfusca group)--On base of Pseudotsuga, 5.

Lecanora sp. (L. varia group)--On Pseudotsuga, 5

Lecanora sp. (L. polytropa group)--On rock, 5.

Lecanora sp. (L. symmicta group)--On Populus, 5; on base of Picea, 6.

Lecanora sp.--On rock, 4.

Lecanora sp.--On Abies, 1.

Lecanora sp.--On wood, 5.

Lecidea cf. auriculata Th. Fr.--On rock, 5.

Lecidea berengeriana (Massal.) Nyl.--On detritus, 3, 7.

*Lecidea cf. moreliensis B. de Lesd.--On rock, 1, 2, 5. Reports of L. tessellata from 1 and 2 were based on this species.

*Lecidea torquens Müll. Arg.--On wood, 5.

Lecidea turgidula Fr.--On Abies, 1.

Lecidea spp.--On rock, 2, 5, 6.

Lecidea sp.--On Picea, 4.

Lecidea sp.--On Abies, 1.

Lecidea sp.--On base of Pinus strobiliformis, 5.

Lecidella carpathica Körber--On rock, 5, 6.

Lecidella cf. dimelaenophila Hertel--On Aspicilia on rock, 5.

Lecidella euphorea (Flörke) Hertel--On base of Pseudotsuga, 5; on Populus, 5.

Lecidella stigmatea (Ach.) Hertel & Leuck.--On rock, 1, 5.

Lecidella sp.--On Picea twigs, 4; on Abies, 6.

Lecidella sp.--On rock, 4.

*Lepraria finkii (B. de Lesd. in Hue) R. C. Harris--On soil and moss over rock, 5, 6.

Lepraria cf. incana (L.) Ach.--On base of Pseudotsuga, 5; on rock, 5.

*Lepraria neglecta (Nyl.) Lettau--On soil, 5.

Lepraria spp.--on soil or moss over rock, 3, 4, 5, 6; on charred wood, 5.

Leprocaulon albicans (Th. Fr.) Nyl. ex Hue--On moss over rock, 5.

Leproplaca chrysodeta (Vainio ex Räsänen) Laundon--On rock, 5.

Leptogium cyanescens (Rabenh.) Körber--On moss over rock, 5.

Leptogium denticulatum Tuck.--On moss over rock, 5.

Leptogium furfuraceum (Harm.) Sierk--On moss over rock, 5.

Leptogium lichenoides (L.) Zahlbr.--On moss over rock, 5.

Leptogium saturninum (Dickson) Nyl.--On moss over rock, 5; on Populus, 5.

Leptogium sp.--On moss over rock, 5.

*Lichenothelia sp.--On rock, 5.

*Melanelia albertana (Ahti) Essl.--On moss over rock, 5.

Melanelia elegantula (Zahlbr.) Essl.--On Populus, 5.

*Melanelia exasperatula (Nyl.) Essl.--On Picea, 1.

Melanelia subolivacea (Nyl. in Hasse) Essl.--On Picea, 5, 6; on Pseudotsuga, 5.

Melanelia cf. substygia (Räsänen) Essl.--On rock, 2, 5, 6. Most of the material lacks soredia and is sometimes abundantly fertile, suggesting that this may be mostly an undescribed species. The report of M. glabroides from 2 was based on this taxon.

Micarea sp.--On base of Pinus strobiliformis, 5; on Abies, 5, 6.

*Miriquidica garovaglii (Shaerer) Hertel & Rambold--On rock, 2.

Nephroma bellum (Sprengel) Tuck.--On base of Abies, 1; on moss over rock, 4, 6.

Nephroma helveticum ssp. sipeanum (Gyelnik) Goward & Ahti--On moss over rock, 1, 3, 5.

Nephroma parile (Ach.) Ach.--On moss over rock, 1, 3, 5, 6.

Nephroma resupinatum (L.) Ach.--On moss over rock, 6.

Ochrolechia pallescens--On Abies, 1; on Pseudotsuga, 5.

Omphalora arizonica (Tuck.) Nash ined.--on rock, 5.

Pachyospora verrucosa (Ach.) Massal.--On trunk of Pseudotsuga, 5.

Pannaria leucophaea (Vahl) P. Jorg.--On rock, 5; on soil, 6.

Pannaria pezizoides (Weber) Trevisan--On soil among moss, 1, 5, 6.

Pannaria praetermissa Nyl. in Chyd. & Furuhj.--On soil over rock, 6.

Pannaria tavaresii P. Jorg.--On moss over rock, 5.

Pannaria sp.--On detritus, 3; on moss, 6, 5.

Parmelia saxatilis (L.) Ach.--On rock, 5.

Parmelia sulcata Taylor--On Picea, 1, 5; on trunk of Pseudotsuga, 5; on Populus, 5; on rock, 5.

Parmeliopsis ambigua (Wulfen in Jacq.) Nyl.--On Abies, 1; on Picea, 1, 3, 5, 6; on wood, 1; on base of Pseudotsuga, 5.

Parmeliopsis hyperopta (Ach.) Arnold--On Abies, 1; on Picea, 1, 3. 5, 6; on base of Pseudotsuga, 5; on Populus, 5; on wood, 5.

*Peltigera aphthosa (L.) Willd.--On soil among moss, 1, 3, 6, 7.

Peltigera canina (L.) Willd.--On soil among moss, 1, 5, 6.

*Peltigera elisabethae Gyelnik--On mossy rock, 5.

Peltigera malacea (Ach.) Funck--On soil, 7.

Peltigera polydactyla (Necker) Hoffm.--On soil among moss, 1, 5, 6.

Peltigera rufescens (Weis) Humb.--On soil, 5. 6.

Peltigera venosa (L.) Hoffm.--On soil, 6.

Pertusaria ophthalmiza (Nyl.) Nyl.--On Picea, 6.

Pertusaria sommerfeltii (Flörke ex Sommerf.) Fr.--On Abies, 1, 5.

Pertusaria wulfenioides B. de Lesd.--On trunk of Pseudotsuga, 5; on Populus, 5.

Pertusaria sp.--On Pseudotsuga, 5.

*Phaeocalicium populneum (Brond. ex Duby) A. Schmidt--On Lecidella euphorea on Populus, 5.

Phaeophyscia decolor (Kashiw.) Essl.--On rock, 5, 6. The material is rather variable, and some specimens may be another species.

Phaeophyscia hispidula (Ach.) Moberg--On moss over rock, 5.

*Phaeophyscia kairamoi (Vainio) Moberg--On mossy rock, 5.

Physcia aipolia (Ehrh. ex Humb.) Fürnr.--On Populus, 5; on Picea, 5.

Physcia biziana (Massal.) Zahlbr.--On rock, 5.

Physcia caesia (Hoffm.) Fürnr.--On rock, 5.

*Physcia cascadensis Magnusson--On rock, 5.

*Physcia dimidiata (Arnold) Nyl.--On rock, 5.

Physcia dubia (Hoffm.) Lettau--On rock, 5, 6.

*Physcia mexicana B. de Lesd.--On moss over rock, 6.

Physcia phaea (Tuck.) Thomson--On rock, 2, 6.

Physcia stellaris (L.) Nyl.--on Picea, 5.

Physcia sp.--On rock, 1, 5.

Physciella nepalensis (Poelt) Essl.--On Populus, 5; on rock, 5.

Physconia detersa (Nyl.) Poelt--On moss over rock, 5.

*Physconia grisea (Lam.) Poelt--On rock, 5. The material is unusual in having pale bluish upper side and partly dark blue-green underside and rhizines, causing it to superficially resemble a Coccocarpia species.

Placynthiella uliginosa (Schrader) Coppins & P. James--On rotten wood, 6; on detritus, 5; on charred wood, 7. The report on Abies from 1 was based on misidentification of a Lecidea sp.

*Placynthium asperellum (Ach.) Trevisan--On rock, 5.

Polychidium muscicola (Swartz) Gray--On moss over rock, 5.

Porpidia macrocarpa (DC. in Lam. & DC.) Hertel & Schwab--On rock, 5, 6, 7.

Protoparmelia badia (Hoffm.) Hafellner--On rock, 1, 2, 5, 6.

**Protothelenella sphinctrinoidella (Nyl.) Mayrh. & Poelt--On moss, 6.

*Pseudephebe minuscula (Nyl.) Brodo & D. Hawksw.--On rock, 2.

Pseudevernia intensa (Nyl.) Hale & Culb.--On trunk of Pseudotsuga, 5; on Picea, 5, 6.

Psora nipponica (Zahlbr.) G. Schneider--On soil over rock, 5, 6.

Psoroma hypnorum (Vahl) Gray--On moss, 6.

Punctelia semansiana (Culb. & C. Culb.) Krog--On rock, 5.

*Punctelia stictica (Duby) Krog--On rock, 2, 4, 5.

Punctelia subrudecta (Nyl.) Krog--On Picea, 1, 5; on Abies, 6.

Ramalina pollinaria (Westr.) Ach.--On rock, 5.

Rhizocarpon badioatrum (Flörke ex Sprengel) Th. Fr.--On rock, 5.

*Rhizocarpon distinctum Th. Fr.--On rock, 1.

*Rhizocarpon eupetraeum (Nyl.) Arnold--On rock, 5.

Rhizocarpon geographicum (L.) DC.--On rock, 2, 5, 6.

*Rhizocarpon obscuratum (Ach.) Massal.--On rock, 1, 6. The report of R. oederi from 1 was based on a misidentification of this species.

Rhizocarpon polycarpum (Hepp) Th. Fr.--On rock, 5, 6.

*Rhizocarpon renneri Poelt--On Dimelaena oreina on rock, 5.

Rhizocarpon riparium Räsänen--On rock, 1, 6.

*Rhizocarpon simillimum (Anzi) Lettau--On rock, 5

*Rhizocarpon sphaerosporum Räsänen--On rock, 5, 6.

Rhizoplaca chrysoleuca (Sm.) Zopf--On rock, 2, 5.

Rhizoplaca melanophthalma (DC. in Lam. & DC.) Leuck. & Poelt--On rock, 5.

*Rhizoplaca subdiscrepans (Nyl.) R. Sant.--On rock, 5.

Rimularia insularis (Nyl.) Rambold & Hertel--On Lecanora rupicola on rock.

Rinodina sp.--On Picea, 5.

Rinodina sp.--On wood (fenceposts), 5.

*Spilonema revertens Nyl.--On rock, 5.

Sporastatia testudinea (Ach.) Massal.--On rock, 2.

*Staurothele areolata (Ach.) Lettau--On rock, 5. Previously often misidentified as S. clopima.

*Staurothele cinereoviridula B. de Lesd. ex Thoms.--On rock, more or less submerged, 5.

*Staurothele clopimoides (Arnold) Steiner--On rock, 5. Specimens with an ochraceous thallus, on wet rocks along streams, may also belong to this species.

Staurothele sp.--On rock, 5. Thallus verrucose-areolate, brown-black.

*Stereocaulon sasakii v. simplex (Riddle) Lamb--On soil, 6.

*Stereocaulon sasakii v. tomentosoides Lamb--On soil, 6.

*Sticta beauvoisii Delise--On moss over rock, on steep, shaded cliff faces, 5. Reports of S. weigelii from Arizona are based on misidentifications of this species.

Toninia squalida (Schleicher ex Ach.) Massal.--On soil, 5.

*Trapelia coarctata (Sm.) M. Choisy in Werner--On rock, 6.

Trapelia? sp.--On rock, 5. Thallus whitish, granular, C-. Possibly undescribed.

Trapeliopsis flexuosa (Fr.) Coppins & P. James--On wood (fencepost), 5.

Trapeliopsis granulosa (Hoffm.) Lumbsch--On Pseudotsuga, 5; on charred wood, 5; on rotten wood, 7.

Tuckermannopsis fendleri (Nyl.) Hale--On Picea, 1, 5; on trunk of Pseudotsuga, 1, 5.

Tuckermannopsis pinastri (Scop.) Hale--On Picea, 1, 5, 6; on base of Pseudotsuga, 1, 5.

Umbilicaria cinereorufescens (Schaerer) Frey--On rock, 5.

Umbilicaria deusta (L.) Baumg.--On rock, 6.

Umbilicaria hyperborea (Ach.) Hoffm.--On rock, 2, 6.

Umbilicaria krascheninnikovii (Savicz) Zahlbr.--On rock, 2, 6.

Umbilicaria sp.--On rock, 6.

Usnea cavernosa Tuck.--On Picea, 1, 4, 5, 6; on Pseudotsuga, 5.

Usnea ceratina Ach.--On Picea, 1.

Usnea filipendula Stirton s. lato--On Picea, 5.

Usnea hirta (L.) Weber ex Wigg.--On Picea, 1, 5; on Pseudotsuga, 5; on wood (fencepost), 5.

Usnea lapponica Vainio s. lato--On Picea, 5.

*Usnea scabrata Nyl.--On Pseudotsuga, 5, 6

Usnea subfloridana Stirton--On trunk of Pseudotsuga, 5; on Picea, 5, 6.

*Usnea cf. tristis Mot.--On wood (fencepost), 5.

Usnea sp.--On Populus, 5.

*Verrucaria hydrela Ach.--On rock, submerged, 6.

*Xanthoparmelia angustiphylla (Gyelnik) Hale--On rock, 5, 6.

*Xanthoparmelia coloradoensis (Gyelnik) Hale--On rock, 2, 5. The report of "Parmelia taractica" from 2 was based on a misidentification of this species.

Xanthoparmelia cumberlandia (Gyelnik) Hale--On rock, 2, 5, 6; on base of Pseudotsuga, 5.

Xanthoparmelia lineola (Berry) Hale--On rock, 2, 5, 6; on base of Pseudotsuga, 5.

Xanthoparmelia mexicana (Gyelnik) Hale--On rock, 5.

Xanthoparmelia montanensis Hale--On rock, 5.

Xanthoparmelia novomexicana (Gyelnik) Hale--On rock, 5.

*Xanthoparmelia subdecipiens (Vainio) Hale--On rock, 5, 6; on wood at base of Pinus strobiliformis, 5.

Xanthoparmelia tasmanica (J. D. Hook. & Taylor) Hale--on rock, 5.

Xanthoparmelia wyomingica (Gyelnik) Hale--On detritus, 2.

Xanthoparmelia sp.--On rock, 5. This appears to be an undescribed species, characterized by narrow, nonisidiate lobes, pale underside, and containing only usnic and protocetraric acids.

Xanthoparmelia spp.--On rock, 4, 5, 6; on wood (fencepost), 5.

Xanthoria candelaria (L.) Th. Fr.--On rock, 5.

Xanthoria elegans (Link) Th. Fr.--On rock, 2, 5, 6.

Xanthoria fallax (Hepp in Arnold) Arnold--On rock, 5.

Xanthoria polycarpa (Hoffm.) Rieber--On Populus, 5.

*Xanthoria ramulosa (Tuck.) Herre--On Populus, 5.

Xanthoria sorediata (Vainio) Poelt--On rock, 2, 5, 6.

*Xylographa abietina (Pers.) Zahlbr.--On decaying wood, 1, 4, 6.

## APPENDIX C:

## SPECIES LISTS BY LOCALITY AND YEAR OF COLLECTION

Accession numbers are those of Nash, except those preceded by "D", which are those of Davis.

### 1. Trail from Sheeps Crossing along West Fork of Little Colorado River, 2987-3139 m (Nash, 1973)

Aspicilia cinerea--On rock, 7824, 7830.

Bryoria fuscescens v. positiva--On Picea, 7838.

Buellia disciformis--On wood, 7880.

Buellia erubescens--On Abies, 7852.

Buellia novomexicana--On rock, 7827.

Caloplaca ferruginea--On Abies, 7850.

Cladonia bacillaris--On base of Pseudotsuga, 7863.

Cladonia chlorophaea--On base of Abies, 7871.

Cladonia coniocraea--On wood, 7884.

Cladonia deformis--On wood, 7883.

Cladonia pyxidata--On soil among mosses, 7882.

Cladonia--On wood, 7832, 7886.

Evernia divaricata--On Picea, 7867.

Flavopunctelia flaventior--On Picea, 7870.

Hypogymnia austerodes--On Picea, 7840.

Hypogymnia spp.--On Picea, 7841, 7842; on Abies, 7858; on Pseudotsuga, 7861.

Hypotrachyna pulvinata--On Picea, 7845.

Lecanora cenisia--On rock, 7823.

Lecanora impudens--On Abies, 7851, 7862.

Lecanora polytropa--On rock, 7849.

Lecanora--On Abies, 7855.

Lecidea turgidula--On Abies, 7859.

Lecidea--On Abies, 7864.

Lecidella stigmatea--On rock, 7825.

Melanelia exasperatula--On Picea, 7879.

Nephroma bellum--On base of Abies, 7866.

Nephroma helveticum v. sipeanum--On boulders among mosses, 7834.

Nephroma parile--On boulders among mosses, 7833

Ochrolechia pallescens--On Abies, 7854.

Pannaria pezizoides--On soil among mosses, 7839.

Parmelia sulcata--On Picea, 7869.

Parmeliopsis ambigua--On Picea, 7847; on Abies, 7857; on wood, 7876.

Parmeliopsis hyperopta--On Abies, 7856; on Picea, 7878.

Peltigera aphthosa--On soil among mosses, 7831.

Peltigera canina--On soil among mosses, 7872.

Peltigera polydactyla--On soil among mosses, 7873.

Pertusaria sommerfeltii--On Abies, 7852.

Physcia--On rock, 7828.

Placynthiella uliginosa--On Abies, 7865.

Protoparmelia badia--On rock, 7825

Punctelia subrudecta--On Picea, 7844.

Rhizocarpon disporum--On rock, 7822.

Rhizocarpon distinctum--On rock, 7829.

Rhizocarpon obscuratum--On rock, 7848. Previously misdidentified as R. oederi.

Rhizocarpon riparium--On rock, 7821.

Tuckermannopsis fendleri--On Picea, 7843, 7868.

Tuckermannopsis pinastri--On Picea, 7846; on Pseudotsuga, 7860; on wood, 7875.

Usnea cavernosa--On Picea, 7835, 7885.

Usnea ceratina--On Picea, 7887.

Usnea hirta--On Picea, 7888.

Usnea--On Picea, 7836, 7837, 7889.

Xylographa abietina--On wood, 7874.

2. Summit of Mt. Baldy, 3533 m (Nash, 1974)

Acarospora chlorophana--On rock, 10,016.

Amygdalaria elegantior--On rock, 10,039.

Buellia lacteoidea--On rock, 10.034-b.

Candelariella vitellina--On rock, 10,017.

Diploschistes muscorum--On detritus, 10,037; 10,043.

Diplotomma alboatrum--On rock, 10,034-a.

Hypogymnia farinacea--On detritus, 10,038. Previously identified as H. austerodes.

Lecanora marginata--On rock, 10,033.

Lecanora polytropa--On rock, 10,029.

Lecanora rupicola--On rock, 10,036.

Lecidea cf. moreliensis--On rock, 10,025. Previously misidentified as L. tessellata.

Lecidea sp.--On rock, 10,040.

Melanelia cf. substygia--On rock, 10,032. Previously misidentified as M. glabroides.

Miriquidica garovaglii--On rock, 10,041.

Physcia phaea--On rock, 10,027.

Protoparmelia badia--On rock, 10,042.

Pseudephebe minuscula--On rock, 10,035.

Punctelia stictica--On rock, 10,021.

Rhizocarpon geographicum--On rock, 10,018, 10,044.

Rhizoplaca chrysoleuca--On rock, 10,022.

Sporostatia testudinea--On rock, 10,028.

Umbilicaria hyperborea--On rock, 10,031.

Umbilicaria krascheninnikovii--On rock, 10,030.

Xanthoparmelia colordoensis--On rock, 10,024. Previously misidentified as X. taractica.

Xanthoparmelia cumberlandia--On rock, 10,019-b.

Xanthoparmelia lineola--On rock, 10,019-a.

Xanthoparmelia wyomingica--On detritus, 10,020.

Xanthoria elegans--On rock, 10,026.

Xanthoria sorediata--On rock, 10,023.

3. East slope of Mt. Baldy, 3383 m (Collected by Nash, 1974)

Bryoria fuscescens v. positiva--On Picea, 10,059.

Cladonia coniocraea--On detritus, 10,048.

Cladonia pleurota--On wood, 10,049.

Hypogymnia physodes--On Pseudotsuga, 10,055.

Hypotrachyna pulvinata--On Pseudotsuga, 10,069.

Lecidea berengeriana--On detritus, 10,051.

Lepraria incana--On moss, 10,058.

Nephroma helveticum--On moss, 10,057.

Nephroma parile--On moss, 10,056.

Pannaria--On detritus, 10,072.

Parmeliopsis ambigua--On Picea, 10,051.

Parmeliopsis hyperopta--On Picea, 10,052.

Peltigera aphthosa--On soil, 10.054.

4. Trail from Sheep's Crossing along West Fork of Little Colorado River, 2870 m (Nash, 1983)

Buellia lakensis--On rock, 21276.

Buellia sp. (spores submuriform)--On Picea twigs, 21294.

Cetraria? sp.--On Picea twigs, 21292.

Cladonia cariosa--On soil, 21282.

Cladonia cenotea--On decaying wood, 21285. (C. ochrochlora?)

Cladonia macrophyllodes--On soil, 21281.

Cladonia pleurota--On decaying wood, 21283.

Cladonia sulphurina--On decaying wood, 21284.

Hypogymnia farinacea--On Picea, 21288.

Hypotrachyna--On Picea, 21290.

Lecanora symmicta--On Picea twigs, 21293.

Lecanora sp.--On rock, 21275, 21277.

Lecidea sp.--On Picea, 21291.

Lecidella sp.--On Picea twigs, 21294.

Lecidella viridans--On rock, 21274.

Lepraria sp.--On moss over boulder, 21280.

Nephroma bellum--On rock, 21278.

Punctelia stictica--On boulder, 21279.

Usnea cavernosa--On Picea, 21289.

Xanthoparmelia--On boulder, 21270, 21271.

Xylographa abietina--On decaying wood, 21286, 21287.

Unknown--On Populus, 21272, 21273.

5. Trail from Phelps Cabin along East Fork of Little Colorado River (Nash, et al., June-July 1990)

Acarospora chlorophana--On cliffs, 27009; on boulders, 27108.

Acarospora fuscata--On rock scree and boulders, 27109.

Acarospora cf. schleicheri--On boulders, 27110.

Acarospora sp. (brown thallus)--On rock, 27010, 27111, 27198.

Aspicilia alphoplaca--On rock, 26950.

Aspicilia cinerea--On boulders, 26942, 27112; on scree rocks, 27199; on cliffs, 27012, 27020, 27021, 27022.

Aspicilia sp. (ochraceous thallus)--On rock, partially submerged, 26800.

Aspicilia sp. (greenish thallus)--On cliffs, 27015.

Aspicilia spp.--On rock, 26988, 27013, 27014, 27016, 27017, 27018, 27019, 27199, D790, D792, D863, D909.

Bacidia sp.--On Populus, 26962. Thallus whitish; apothecia black; spores 30-35 x 1-1.5 um.

Bellemerea cinereorufescens--On rock.

Bryoria fuscescens v. positiva--On trunk of Pseudotsuga, 26833, 26869; on Picea, 26816, 26819, 26966, 27149.

Buellia erubescens--On wood at base of Pinus strobiliformis, 26937; on Pseudotsuga, 27319.

Buellia immersa--On rock, 27025.

Buellia leptocline--On rock, 27027, 26941.

Buellia novomexicana--On rock, 26814, 27190.

Buellia punctata--On Pseudotsuga, 27316.

Buellia semitensis--On rock, 27088, 27346.

Buellia subdisciformis--On rock, 27029.

Buellia sp. (submuriform spores)--On Pseudotsuga, 26879.

Buellia spp.--On rock, 26815, 26943.

Caloplaca arenaria--On rock, 27113.

Caloplaca cerina--On Populus, 26951.

Caloplaca microphyllina--On wooden fenceposts, 26825, D886.

Caloplaca pelodella--On rock, 26989.

Caloplaca saxicola--On rock, 27033.

Caloplaca sipeana--On boulders, 27030, 27032.

Caloplaca trachyphylla--On rock, 27031.

Caloplaca sp.--On rock, D780.

Candelaria concolor--On cliffs, 27031.

Candelariella rosulans--On rock, 27036-a, 27115.

Candelariella vitellina--On rock, 27114, D783.

Candelariella sp.--On rock, 27035.

Candelina submexicana--On exposed rock, 26801, D884.

Catapyrenium lachneum--On rocks in full sun, 26952.

Cetraria coralligera--On Pseudotsuga, 26870, 27318.

Cladonia bacillaris--On Picea, 26817; on base of Pseudotsuga, 26971; on rotten wood, 26968.

Cladonia cariosa--On soil, 26967, 27001.

Cladonia cenotea--On moss, 26967, 26990, 27003-27005.

Cladonia cervicornis ssp. verticillata--On soil, 26991.

Cladonia chlorophaea--On decaying moss, 26975, 26978 26971; on soil, 27002.

Cladonia coccifera--On soil, 26972, 26979.

Cladonia coniocraea--On base of Pseudotsuga; on wood, D910, D911.

Cladonia deformis--On soil, 26854, 26974.

Cladonia fimbriata--On base of Pseudotsuga (voucher for quadrat).

Cladonia macrophyllodes--On soil, 26965, 26970, D768.

Cladonia ochrochlora--On decaying moss, 26980.

Cladonia pocillum--On soil, 26981.

Cladonia polycarpioides f. epiphylla--On soil, 26855.

Cladonia pyxidata--On base of Pseudotsuga, 27321; on moss, D770, D882.

Cladonia subradiata--On base of Pseudotsuga (voucher for qudrat).

Cladonia sulphurina--On soil, 26856, 26970.

Cladonia spp. (mostly basal squamules only)--On soil, 26973, D769; on shelf fungus. D853; on moss, D860, D875; on rotten wood, 26964, D835; on base of Pseudotsuga, 27322.

Cyphelium tigillare--On wood, 27197; on wooden fenceposts, 26825.

Dermatocarpon intestiniforme--On rock, 26857, 27037, D771.

Dermatocarpon miniatum--On rock, 27038.

Dermatocarpon reticulatum--On cliff, 26953.

Dimelaena oreina--On rock, 27039, 27116.

Diploschistes scruposus--On rock, 27040, D849.

Evernia divaricata--On Picea, 27150.

Flavoparmelia caperata--On Pseudotsuga, 26835; on wooden fencepost.

Flavopunctelia flaventior--On cliff, 26834, 27041; on boulders, 26944, 27117; on Picea, 27151.

Flavopunctelia praesignis--On Picea, 27152.

Flavopunctelia soredica--On trunk of Pseudotsuga, 26872, 26974, 27315; on Picea, 26802, 27153; on Abies, D874; on cliffs, 27042.

Heterodermia cf. casarettiana--On cliffs, 26836, 26919-a, 26932b; on shaded mossy boulders, 26945; on Populus, 26954.

Heterodermia hypoleuca--On Pseudotsuga, 26882; on mossy rock, 26919-b, 26933.

Heterodermia sp. (sorediate)--On exposed boulders, 27133.

Hypocenomyce anthracophila--On Pseudotsuga, 26975.

Hypocenomyce friesii--On trunk of Pseudotsuga, 26837.

Hypocenomyce scalaris--On Pseudotsuga, 26876.

Hypocenomyce xanthococca--On Pinus strobiliformis, 26839 (fertile); on wood, 26838 (pycnidia only).

Hypogymnia austerodes--On trunk of Pseudotsuga (No voucher); on Picea, 27154.

Hypogymnia bitteri--On trunk of Pseudotsuga, 26840, 27320; on Picea, 27115, D916; on wood, D773.

Hypogymnia physodes--On trunk of Pseudotsuga, 26841; on Picea, 27156.

Hypotrachyna laevigata--On trunk of Pseudotsuga, D774, and voucher for quadrat.

Hypotrachyna polydactyla--On Pseudotsuga, 26842.

Hypotrachyna pulvinata--On Picea, 26818, 26820, 27157; on Pseudotsuga, 26873, D847.

Hypotrachyna rockii--On Abies, D775.

Imshaugia aleurites--On trunk of Pseudotsuga, 26843, 26858, D848.

Imshaugia placorodia--On trunk of Pseudotsuga, 27335, D774.

Lasallia papulosa--On cliff, 27055, 27324.

Lasallia pensylvanica--On cliff, 27056.

Lasallia pustulata--On cliff, 27057.

Lecanora argopholis--On boulders, 27118, 27191.

Lecanora cenisia--On rock, 26992, 27043, 27119.

Lecanora demissa--On cliff, in shaded crevices, 27044 (?), 27045.

Lecanora intricata--On rock scree, 27049.

Lecanora laatokkaensis--On rock scree, 27200; on boulders in meadow, 27123.

Lecanora mazatzalensis--On rock scree, 27201; on boulders in meadow, 27124.

Lecanora muralis--On cliffs, 27046; on boulders, 27120.

Lecanora cf. opiniconensis--On cliffs, 26859, 27051; on exposed boulders, 27196.

Lecanora polytropa--On rock, 26994, 27350; on wood, 27325.

Lecanora rupicola--On boulders, 27122, 27186, D793, D907; on cliff, 27048.

Lecanora saligna--On wood: at base of Pseudotsuga; at base of Pinus strobiliformis, 26938; on Abies, 26877; on wooden fencepost, 26828.

Lecanora sp. (L. symmicta group)--On Populus, 26902.

Lecanora sp. (L. subfusca group)--On base of Pseudotsuga, 27313.

Lecanora sp. (L. polytropa group)--On rock, 26993, 27047, 27121, D761.

Lecanora sp. (L. varia group)--On Pseudotsuga, 26895.

Lecanora spp.--On rock, 26813, 27050, 27051, 27125, 27126, 27127, 27196, D868, D869

Lecanora spp.--On wood, 26897, 26900, D887; on wooden fencepost, 26827; on Abies, 26878.

Lecidea cf. auriculata--On rock, 26984.

Lecidea cf. moreliensis--On rock, 27052-a, 27184, 27185, 27188, 27193, 26803, D781.

Lecidea torquens--On wood, 26898.

Lecidea sp. (L. atrobrunnea complex, with brown, areolate thallus)--On rock, 27052-b, 27195, 27052, 27053, 27054, 27176, 27177, 27178, 27179, 27202.

Lecidea spp.--On rock, 27345, D876, D885, D903, D904, D906.

Lecidea sp.--On wood at base of Pinus strobiliformis, 26939; on wooden fencepost, 26829.

Lecidea sp.--On Pseudotsuga, 26879.

Lecidella carpathica--On rock, 27323.

Lecidella cf. dimelaenophila--On Aspicilia on rock, 27347.

Lecidella euphorea--On Populus, 26903, 26904, 27326; on base of Pseudotsuga.

Lecidella stigmatea--On rock, 26985.

Lepraria finkii--On soil and moss, 27007.

Lepraria incana--On base of Pseudotsuga (voucher for quadrat).

Lepraira neglecta--On soil, 27006, 27059a, 27327.

Lepraria spp.--On rock scree and shaded mossy boulders, 26947; on rock, 27058, 27059-b, 27060, D779, D784, D864, D867, D918; on soil or moss, D852; on burnt wood, D919, D920.

Leprocaulon albicans--On soil and moss over rock, 26920, 27328.

Leproplaca chrysodeta--On shaded rock faces, 27061.

Leptogium cyanescens--On moss over rock, 26921, 26924.

Leptogium denticulatum--On moss over rock, 26922, 27330.

Leptogium furfuraceum--On moss over rock, 26923.

Leptogium lichenoides--On moss over rock, 26925.

Leptogium saturninum--On moss over boulder, 26860; over cliff, 26926; on Populus, 26905.

Lichenothelia sp.--On rock, 27104.

Melanelia albertana--On moss over cliff, 26936.

Melanelia elegantula--On Populus, 26955.

Melanelia cf. substygia--On rock, 26861, 26862, 27062, 27063, 27064, 27065, 27066.

Melanelia subolivacea--On Picea, 26821, 27158; on Pseudotsuga, 26880; on Abies, D870, D921, D922.

Micarea sp.--On wood, on base of Pinus strobiliformis, 26938; on base of Abies, 27331.

Nephroma helveticum var. sipeanum--On moss over cliff, 26928

Nephroma parile--On moss over rock, 26928, 26995.

Ochrolechia pallescens--On trunk of Pseudotsuga, 26844.

Omphalora arizonica--On rock, 27000.

Pachyspora verrucosa--On trunk of Pseudotsuga. 27323.

Pannaria pezizoides--On humus, 26996.

Pannaria praetermissa--On soil, 27333, 27334.

Pannaria tavaresii--On moss over cliff, 26929.

Pannaria sp.--On soil, 27336.

Parmelia saxatilis--On cliffs, 27067.

Parmelia sulcata--On trunk of Pseudotsuga, 26846, 27317; on Abies, 26956; on Picea, 27159; on Populus, 26906 (?); on cliffs, 26845, 27068.

Parmeliopsis ambigua--On base of Pseudotsuga, 26881, 27314, D842, D846; on Picea, 27175.

Parmeliopsis hyperopta--On base of Pseudotsuga, 26901; on Populus; on wood, 26995.

Peltigera canina--On moss over cliff, 26930, 26957.

Peltigera elisabethae--On soil or moss over rock, 26948, D902.

Peltigera rufescens--On soil or moss over rock, 26931, D766, D767.

Pertusaria sommerfeltii--On Abies, 26958.

Pertusaria wulfenoides--On wood, D776; on trunk of Pseudotsuga, 26847, D845; on Populus, 26907.

Pertusaria sp. (whitish thallus; pruinose lecanorine apothecia) --On Pseudotsuga, 27008.

Phaeocalicium populneum--On Lecidella euphorea on Populus, 27332.

Phaeophyscia decolor--On rock (cliffs or boulders), 26998, 27073, 27074, 27075, 27129.

Phaeophyscia hispidula--On mossy cliffs, 26848, 26932, 27076; on boulders, 26949, 27128.

Phaeophyscia kairamoi--On moss on cliff, 26866.

Physcia aipolia--On Picea, 26822; on Populus, 26908; on Pseudotsuga, 26883.

Physcia biziana--On cliff, 26863, 27077, 27080; on moss, D861.

Physcia caesia--On cliff, 26849, 27078; on boulders, 27130.

Physcia cascadensis--On rock, 27132.

Physcia dimidiata--On cliffs, 27079, 27081, 27082.

Physcia dubia--On boulders, 27131

Physcia mexicana--On rock, D865.

Physcia stellaris--On Pseudotsuga, 26884; on Picea, 27160.

Physcia sp.--On rock, D851.

Physciella nepalensis--On Populus, 26909; on cliffs, 27083; on rocks partially submerged in creek, 26805.

Physconia detersa--On moss over cliff, 26864, 27084.

Physconia grisea--On cliffs, 27107.

Placynthiella uliginosa--On detritus, 26977; on rotten wood, 27268.

Placynthium asperellum--On rock, 27348.

Polychidium muscicola--On moss, 27329.

Porpidia macrocarpa--On cliff, 26865.

Protoparmelia badia--On boulders, 26805.

Pseudevernia intensa--On trunk of Pseudotsuga, 26885; on Picea, 26807, 27161; on Abies, D871, D872, D873.

Psora nipponica--On soil over rock, 26932, 27337.

Punctelia semansiana--On cliffs, 27070.

Punctelia stictica--On cliff, 27071.

Punctelia subrudecta--On mossy cliff, 26850, 27072, 27338; on Picea, 26823, 27162; on Pseudotsuga, 26886.

Ramalina pollinaria--on steep face of large boulder, 27082.

Rhizocarpon badioatrum--On rock, 27189.

Rhizocarpon disporum--On rock, 27085, 27092, 27093, D785, D786.

Rhizocarpon eupetraeum--On rock, 27091.

Rhizocarpon geographicum--On rock, 27086, 27089, 27181, D883.

Rhizocarpon obscuratum--On rock, 27094.

Rhizocarpon polycarpum--On rock, 26808, 26999.

Rhizocarpon renneri--On Dimelaena oreina on rock.

Rhizocarpon simillimum--On rock, 27095.

Rhizocarpon sphaerosporum--On rock, 27087, 27181, 27182, 27183, 27203, D760, D762, D905.

Rhizocarpon sp.--On rock, D789.

Rhizoplaca chrysoleuca--On exposed boulders, 27134, 27135, 27136, D782, D788.

Rhizoplaca melanophthalma--On rock, 27137.

Rhizoplaca subdiscrepans--On exposed boulders, 27138.

Rinodina spp.--On wooden fencepost; on Picea, 27163; on Populus, 26903 (with Lecidella euphorea).

Spilonema revertens--On cliff, 27105.

Staurothele areolata--On cliffs, 26867, 27096, 27097, 27194;

Staurothele cinereoviridula--On rock along creek, more or less submerged, 26809.

Staurothele clopimoides--On rock, 27349.

Staurothele cf. clopimoides (ochraceous thallus)--On rock along creek, more or less submerged, 26810.

Staurothele sp. (brown-black thallus)--On cliff, 27097.

Sticta beauvoisii--On moss over shaded cliffs, 26935.

Toninia squalida--On soil, 27339.

Trapelia? sp.--On rock, 26986.

Trapeliopsis flexuosa--On wooden fencepost, 26830.

Trapeliopsis granulosa--On Pseudotsuga, 26895; on charred wood, 27342.

Tuckermannopsis fendleri--On trunk of Pseudotsuga, 26851, 26887; on Picea, 26811, 26824, 27164.

Tuckermannopsis pinastri--On base of Pseudotsuga, 26851, D844; on Picea, 27165.

Umbilicaria cinereorufescens--On cliffs, 27098, 27340; on boulders, 26868.

Umbilicaria deusta--On rock, 27099.

Usnea cavernosa--On trunk of Pseudotsuga, 26888; on branches of Picea, 26812, 27166.

Usnea filipendula--On Picea, 27170, 27351.

Usnea hirta--On Abies, D751, D879; on trunk of Pseudotsuga, 26889; on Picea, 27167; on wooden fencepost, 26831.

Usnea lapponica s. lato--On Picea, 27168, 27171; on Abies, D880.

Usnea cf. scabrata--On Abies, D881, D888; on Pseudotsuga, 26890.

Usnea subfloridana--On trunk of Pseudotsuga; on branches of Picea, 27169; on wood, D917.

Usnea cf. tristis--On wooden fencepost, 26832.

Usnea sp.--On Populus, 26910 (young thallus too small to identify to species).

Vestergrenopsis elaeina--On rock, 27341.

Xanthoparmelia angustophylla--On rock, 27141.

Xanthoparmelia coloradoensis--On rock, 26852, 26891, 26960, 26982, 27139, 27142, D913.

Xanthoparmelia cumberlandia--On base of Pseudotsuga; on rock, 26959, 26983, 27140, 27147, D763, D764, D765, D850, D866, D912, D914, D915.

Xanthoparmelia lineola--On rock, 26976, 27142, 27145, 27147, D877, D878; on wood at base of Pinus strobiliformis, 26940; on Pseudotsuga.

Xanthoparmelia mexicana--On rock, 27343.

Xanthoparmelia montanensis--On rock, 27144.

Xanthoparmelia novomexicana--On rock, D778, D794, D914-b.

Xanthoparmelia subdecipiens--On rock, 26853, 27148; on wood at base of Pinus strobiliformis, 26941.

Xanthoparmelia tasmanica--On rock, 27143.

Xanthoparmelia sp. (narrow lobed; protocetraric acid)--On rock, 27344.

Xanthoparmelia spp.--On rock, 26968, D791, D850; on base of Pseudotsuga, 26892.

Xanthoria candelaria--On rock, 27100.

Xanthoria elegans--On rock, 27101.

Xanthoria fallax--On cliff, 27102.

Xanthoria polycarpa--On Populus, 26910, 26961.

Xanthoria ramulosa--On Populus, 26912, D854.

Xanthoria sorediata--On cliffs, 27103, D858, D859, D862.

## 6. Trail along West Fork of Little Colorado River (Nash, et al., June 1990)

Acarospora chlorophana--On rock, 27255.

Acarospora sp. (brown thallus)--On rock, 27254.

Aspicilia sp.--On rock, 27297.

Bellemerea alpina--On rock, D893.

Bryoria fuscescens v. positiva--On Picea, 27204, 27213, 27283; on Abies, D841.

Buellia erubescens--On base of Abies, 27235.

Buellia sp. (sorediate)--On soil, 27229.

Candelariella vitellina--On large cliff, 27249 (with Rhizocarpon sphaerosporum).

Catapyrenium zahlbruckneri--On large cliff, 27236.

Chaenotheca furfuracea--On rock under overhang, 27268.

Cladonia cenotea--On rotten wood, D899, D910, D911.

Cladonia chlorophaea--On soil and moss, 27271-b, D894, D895b, D896-898.

Cladonia coccifera--On soil, 27260.

Cladonia deformis--On rotten wood, 27261.

Cladonia fimbriata--On soil and moss, D900.

Cladonia pyxidata--On soil or moss, 27271-a.

Cladonia sp.--On soil or moss, 27262, 27271-c, D895-a, D899.

Evernia divaricata--On Picea, 27214.

Hypogymnia austerodes--On Picea, 27205, 27284.

Hypogymnia bitteri--On Picea, 27206, 27285; on Pseudotsuga, 27237.

Hypogymnia farinacea--On Picea, 27286.

Hypogymnia metaphysodes--On Picea, 27287.

Hypogymnia physodes--On Picea, 27288; on Pseudotsuga, 27234.

Hypogymnia tubulosa--On Picea, 27207, 27215.

Hypogymnia sp.--On Picea, 27289.

Hypotrachyna pulvinata--On Picea, 27216.

Lecanora cenisia--On large cliff, 27238, 27298.

Lecanora muralis--On large cliff, 27239.

Lecanora sp. (L. symmicta group)--On base of Picea, 27228.

Lecidea sp. (thin whitish thallus)--On rock, 27226-b, 27304.

Lecidea spp.--On rock, 27224, 27240.

Lecidella carpathica--On large cliff, 27241.

Lepraria finkii--On soil over rock, 27273-a.

Lepraria sp.--On soil over rock, 27273-b.

Melanelia subolivacea--On Picea, 27290.

Melanelia cf. substygia--On rock, 27256.

Micarea sp.--On base of Abies, 27253.

Nephroma bellum--On moss over rock, 27274.

Nephroma parile--On moss over rock, 27275, D755.

Nephroma resupinatum--On moss over rock, 27230.

Pannaria leucophaea--On soil over cliff, 27242-a.

Pannaria pezizoides--On soil, 27225, 27276.

Pannaria praetermissa--On soil over cliff, 27242-b.

Parmelia sulcata--On Picea, 27209.

Parmeliopsis ambigua--On Picea, 27291, D759.

Parmeliopsis hyperopta--On Picea, 27292; on wood, D752 (with P. ambigua).

Peltigera aphthosa--On soil, 27210, 27277.

Peltigera canina--On soil and moss, 27278, D754.

Peltigera cf. polydactyla--On soil and moss, 27280, D757.

Peltigera rufescens--On soil, 27279, D889, D890.

Peltigera venosa--On soil and moss, 27270, D758.

Peltigera sp.--On soil over large cliff, 27244.

Phaeophyscia decolor--On large cliff, 27244, 27299.

Physcia dubia--On rock, 27300.

Physcia mexicana--On moss over rock, 27281.

Physcia phaea--On large cliff, 27245.

Placynthiella uliginosa--On rotten wood, 27246, 27269.

Porpidia macrocarpa--On rock, 27231.

Protoparmelia badia--On large cliff, 27247.

Protothelenella sphinctrinoidella--On moss, 27233.

Pseudevernia intensa--On Picea, 27211, 27293, D901.

Psora nipponica--On soil over large cliff, 27248.

Psoroma hypnorum--On moss, 27232, 27282.

Punctelia subrudecta--On Abies, 27218.

Rhizocarpon geographicum--On rock, 27251, D837, D838, D891.

Rhizocarpon obscuratum--On rock, 27303.

Rhizocarpon polycarpum--On rock, 27227, 27263, 27302.

Rhizocarpon riparium--On rock, 27301

Rhizocarpon sphaerosporum--On large cliff, 27249.

Rinodina sp.--On Picea, 27294.

Stereocaulon sasakii v. simplex--On soil, on ridgecrest, 27264.

Stereocaulon sasakii v. tomentosoides--On soil, on ridgecrest, 27265.

Trapelia coarctata--On rock, 27226.

Tuckermannopsis pinastri--On Picea, 27219, D753.

Umbilicaria deusta--On rock, on ridgecrest, 27266.

Umbilicaria hyperborea--On large cliff, 27250.

Umbilicaria kraschenninikovii--On rock, 27257.

Umbilicaria sp.--On rock, on ridgecrest, 27267.

Usnea cavernosa--On Picea, 27220.

*Usnea* cf. *lapponica*--On *Picea*, 27212; on *Abies*, D839, D892.

*Usnea scabrata*--On *Picea*, 27221.

*Usnea subfloridana*--On *Picea*, 27295; on *Abies*, D840.

*Usnea* sp.--On *Piucea*, 27221.

*Verrucaria hydrela*--On rock, submerged in stream, 27222.

*Xanthoparmelia cumberlandia*--On rock, 27306, 27308, D834.

*Xanthoparmelia lineola*--On large cliff, 27252.

*Xanthoparmelia subdecipiens*--On rock, 27258.

*Xanthoparmelia* spp.--On rock, 27222.

*Xanthoria elegans*--On rock, 27259.

*Xanthoria sorediata*--On rock, 27309.

*Xylographa abietina*--On wood, 27296.

7. Trail from W. Fork Little Colorado River to Phelps Cabin, 2850 m (Nash, September 1990)

Cladonia cariosa--On soil, 27352.

Cladonia cenotea--On rotten wood, 27356, 27358.

Cladonia deformis--On rotten wood, 27354(2).

Cladonia fimbriata--On soil, 27353.

Cladonia glauca--On rotten wood, 27354.

Cladonia sulphurina--On rotten wood, 27357.

Hypogymnia bitteri--On Picea, 27359, 27360.

Hypogymnia physodes--On Picea, 27361.

Hypotrachyna pulvinata--On Picea, 27362.

Lecanora symmicta--On Picea, 27363.

Lecidea berengeriana--On soil, 27369.

Peltigera aphthosa--On moss, 27364.

Peltigera malacea--On soil, 27365.

Placynthiella uliginosa--On charred wood, 27368.

Porpidia macrocarpa--On rock, 27366.

Trapeliopsis granulosa--On rotten wood, 27367.

## LIST OF PROTOCOLS, EQUIPMENT AND SUPPLIES USED

### Protocols

The methods used in this study are based partly on those in the October 17, 1988 draft Lichen Monitoring Protocol for U.S. Forest Service Region 5. Standard methods of collecting, curating and identifying the lichens (including use of thin-layer chromatography for identification of lichen secondary metabolic products). Quantitative sampling was done according to the procedures described in the Methods section of the text.

### Equipment

Wild/Leitz dissecting microscope with fiber-optic lighting.

Wild/Leitz compound microscope.

### Supplies

Paper bags for collecting samples.

Hammer, chisel and knife for removing lichens or substrate in the field.

100% cotton paper for packets to contain specimens.

3 x 5" index cards for gluing rocks or bark with lichens, to go in the packets.

Razor blades for hand-sectioning specimens; microscope slides and cover slips.

10% aqueous potassium hydroxide, potassium hypochlorite solution (household bleach), dilute alcoholic solution of paraphenylenediamine, concentrated nitric acid, and 1.5% iodine-potassium iodide solution, for spot tests of lichen chemicals.

Silica gel thin-layer chromatography plates, acetone for extraction, glass shell vials, capillary tubes, developing tank, and solvents as described by Culberson & Kristinsson, 1970, J. Chromatog. 46: 85-93 (with slight modifications).

# GLOSSARY

The following is a guide to the most frequently used terms used in the keys to the lichens of Mt. Baldy Wilderness. Recent textbooks or identification guides to lichens (e.g., M. Hale, 1979, How to Know the Lichens, Wm. C. Brown Co., Dubuque, Iowa) should be consulted for illustrations and further descriptions of the terms and methods used in identifying lichens.

## Chemical Features and Tests

The various "acids" referred to, and other substances such as ATRANORIN AND ZEORIN, are usually identified by a standardized thin-layer chromatography technique developed by C. Culberson (Journal of Chromatography 72: 113-125 (1972), 238: 483-487 (1982), with substitution of toluene for benzene. Some of these substances can also be identified by their color or by their reactions with ultraviolet (UV) light or with the following reagents (which are applied with a capillary tube to fragments of the lichen under a dissecting scope, or to sections under a compound microscope):

C--Household bleach.

I--Iodide-potassium iodide solution.

K--10% potassium hydroxide in water.

$HNO_3$--concentrated nitric acid.

P or Pd--dilute solution of paraphenylenediamine in ethanol (prepared fresh). Will stain paper and clothing; care should be taken to discard the tested fragments.

## Morphological/Anatomical Features

ADNATE--Sitting on the surface, but closely attached over the entire lower side.

AMPHITHECIUM--Margin of the apothecium, as seen in vertical section under a compound microscope.

APOTHECIUM (APOTHECIA)--Disc-like or cup-shaped fruiting body.

AREOLES (AREOLAE, AREOLATE)--Tile-like units, forming ior covering the thallus.

ASCUS (ASCI)--Sac producing the spores inside the fruiting body.

CEPHALODIA--Wartlike structures containing bluegreen algae, on or in the thallus of a lichen having green algae as the main photobiont.

CORTEX (CORTICATE)--Skin-like layer on surface of the thallus.

CRENATE--With a scalloped edge (CRENULATE = finer scallops).

CRUSTOSE--Crustlike, forming a layer closely attached to the substrate, not removable intact.

DISC--Central part of apothecium as seen from above, usually surrounded by a margin or rim.

EFFIGURATE--Irregularly elongated.

EPIHYMENIUM--Top layer of the area where the spores are produced inside the fruiting body.

EXCIPLE or EXCIPULUM--The margin or rim of an apothecium.

FOLIOSE--Leaflike, flattened in cross-section, lying mostly parallel to the substrate, with distinct upper and lower sides, removable intact.

FRUITING BODY--Structure in which the spores are produced, for sexual reproduction; usually visible as discs, cups, or tiny dots.

FRUTICOSE--Stalked, shrublike, or beardlike, composed of branched or unbranched stalks, often rounded in cross-section, erect to hanging, attached to the substrate only at the base, or not attached at all.

GELATINOUS--Swollen and translucent when wet; the algae are scattered throughout the inside of the thallus, rather than confined to a distinct layer.

HYMENIUM--Area inside the fruiting body where the asci and spores are produced.

HYPHAE--Threadlike microscopic structures composing the fungal part of the lichen.

HYPOTHALLUS--Purely fungal tissue underneath the main thallus of a crustose lichen.

HYPOTHECIUM--Tissue below the area where the spores are produced inside the fruiting body.

IMMARGINATE--Without a margin or rim around the disc.

ISIDIA (ISIDIATE)--Tiny granular to cylindrical or coral-like extensions of the upper surface of the thallus, usually functioning in asexual dispersal.

LAMINAL--Occuring on the upper surface, rather than near the margins.

LECANORINE--Margin of apothecium similar in color to the thallus, and containing algae (as in Lecanora).

LECIDEINE--Margin of apothecium similar in color to the disc, and lacking algae (as in Lecidea).

LOBATE--Crustose, but with radiating, ± elongated extensions (LOBES) around the periphery, almost foliose, but not removable intact.

MEDULLA--Purely fungal tissue inside the thallus.

MURIFORM--With both longitudinal and transverse walls.

PAPILLAE (PAPILLOSE, PAPILLATE)--Small pimple-like bumps.

PARAPHYSES--Vertical threadlike structures between the spore sacs inside the fruiting body.

PERITHECIUM (PERITHECIA)--Flask-like fruiting body immersed in the thallus, opening only by a microscopic pore.

PHOTOBIONT--Green algae (with distinct chloroplasts and nucleus) or bluegreen algae (cyanobacteria, without chloroplasts or nucleus).

PHYLLOCLADIA--Granular to coral-like structures on the stalks of Stereocaulon, usually whitish and distinctly different in texture from the rest of the stalk.

PODETIA--Erect, hollow stalks (if solid, = PSEUDOPODETIA).

PRUINA (PRUINOSE)--Pale, powdery "frosting" on the surface.

PSEUDOCYPHELLAE--Pale pores in surface of the lichen, exposing the medulla; not recessed into the surface as in cyphellae.

PUSTULES--Blister-like structures.

PYCNIDIA--Tiny bumps or pits containing a flask-shaped cavity opening by a microscopic pore and producing spores on the tips of hyphae.

PYCNOSPORES--Spores produced in pycnidia, functioning either for asexual reproduction (conidia) or as male gametes (spermatia).

RHIZINES--Rootlike holdfasts on underside of a foliose lichen (if microscopic, = RHIZOIDAL HYPHAE).

SEPTATE--With one or more cross-walls.

SESSILE--Sitting on the surface (not immersed).

SOREDIA (SOREDIATE)--Powdery to granular structures erupting from the algal layer, containing algae, and usually forming distinct patches (SORALIA), and functioning in asexual dispersal.

SPORES--Microscopic structures originating in the asci (sacs) inside the fruiting body.

SQUAMULOSE--Scalelike, composed of numerous scattered to crowded or overlapping units (SQUAMULES) that are partly lifted off the substrate.

SUBSTRATE--What the lichen is growing on.

THALLUS--The body of the lichen.

TOMENTUM (TOMENTOSE)--Mat of hairs, appearing feltlike or wooly.

UMBILICATE--Squamulose or foliose, but with each unit attached to the substrate by a single short stalk.

VEINS--Weakly to strongly raised, branching cords on the underside of Peltigera, often darker than the rest of the underside (sometimes fused so that only tiny whitish areas are visible between them).

VERRUCULOSE--Composed of convex, wartlike units.